POTATO DISEASES and THEIR CONTROL

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POTATO diseases are caused by fungi, bacteria, viruses, nematodes, and environmental and physiological factors. Flea beetles, leafhoppers, and psyllids cause injuries that may be confused with diseases due to infections.

The occurrence and the severity of the various diseases are influenced largely by environmental conditions such as humidity and temperature, but certain measures can be taken to prevent or control some diseases.

Growers of potato table stock are directly concerned only with diseases that affect eating quality or that reduce yields. In order to determine what diseases occur and which need treatment they must have enough information to distinguish them. This bulletin contains descriptions of diseases with which growers of table stock are concerned and gives the measures recommended for their control.

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POTATO DISEASES AND THEIR CONTROL

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Contents

DISEASE PROBLEMS OF GROWERS OF TABLE STOCK

POTATO growing consists of two specialized branches: the production of seed potatoes and that of table stock. Growers of both have disease problems, but they are not the same. Growers of table stock are directly concerned only with diseases that affect the eating quality of potatoes or that reduce yields. If progressive they plant only certified seed potatoes; such potatoes contain only minimum amounts of tuber-borne diseases. Frequently they use the resistant varieties that are available. They use the best rotation and other cultural and storage practices to reduce diseases that affect the eating quality of tubers.

In contrast to the growers of certified seed, growers of table stock make no effort to eliminate field plants affected with virus or other diseases that do not affect eating quality. If necessary they treat seed potatoes to control rhizoctonia canker. During the growing season they spray to prevent such diseases as late blight, early blight, and psyllid yellows and injury from flea beetles and leafhoppers that greatly reduce yields or affect tubers.

In order to determine which diseases occur and which need treatment, growers of table stock must have enough information to distinguish the various diseases.

IMPORTANCE OF CERTIFIED SEED POTATOES

The quality of seed planted is one of the most important factors in the production of profitable potato crops. For this reason only certified seed should be planted; such seed is as free from disease as possible, free from varietal mixture, and reasonably uniform in shape and size.

During recent years the quality of seed potatoes has greatly improved because additional knowledge has been obtained on methods of disease control and the requirements for seed-potato certification are more rigid.[1]

GENERAL CONTROL MEASURES

CROP ROTATION

As a number of disease-producing organisms live over in the soil after the digging of the potatoes, it is advisable to rotate potatoes with nonsusceptible crops so as to eliminate or reduce the potato-infecting organisms by starvation. This method is especially applicable to such diseases as rhizoctonia canker, fusarium wilt, and root knot. Some of the organisms producing disease in potatoes can remain in the soil for more than 3 years. Whenever it can be arranged, it is best to grow potatoes on the same land not oftener than once every 4 or 5 years and meanwhile to plant crops not affected by potato parasites. Not all disease-producing organisms living in the soil can be eradicated by crop rotation, but the extent of infection may be reduced by this method.

SEED DISINFECTION

When new land is being used or old land is not heavily infested, it is advisable to treat seed potatoes before they are planted for the control of rhizoctonia canker. Disinfection may be regarded as a factor in raising better crops only insofar as it destroys parasites on the outside of the tubers. In the case of internal troubles other methods of control must be used. Ordinarily whole tubers are treated, but in some cases it may be desirable to treat cut seed pieces. Although seed pieces have been treated with satisfactory results in some localities, additional tests should be conducted before such treatment can be recommended for general use.

Several methods of treating potato tubers may be used. These include treatment with (1) mercuric chloride (corrosive sublimate), (2) acidulated mercuric chloride, (3) hot formaldehyde, and (4) yellow oxide of mercury.

Mercuric Chloride

The effectiveness of mercuric chloride (corrosive sublimate) as a disinfectant to control rhizoctonia canker of potatoes has been known

[1] For a discussion of the production of certified seed potatoes, growers of such stock are referred to Circular 764, Production of Disease-Free Seed Potatoes.

for a long time. The original formula prescribes a solution of 1 part of mercuric chloride to 1,000 parts of water, or 4 ounces to 30 gallons of water. Potato tubers are treated in such a solution for 30 minutes to 2 hours. Mercuric chloride goes into solution very slowly in cold water; therefore, it should be dissolved in a small volume of hot water. The solution should be prepared and used in wooden, enamel, or concrete containers. The solution decreases in strength with use. To correct this decrease, one-half ounce of the chemical should be added for every 4 bushels of potatoes treated for 2 hours. If a shorter treatment is used, the amount of chemical added should be reduced proportionately. If the potatoes are treated 1½ hours, add three-eighths ounce. Enough water should be added each time to bring the solution up to its original volume. Make up a fresh solution after four treatments. Wetting the potatoes for 20 to 24 hours before treatment helps to remove dirt, softens the sclerotia of *Rhizoctonia* (p. 23), and makes the disinfection more effective.

Mercuric chloride in full strength is very poisonous; even the solution containing 1 part of the chemical to 1,000 parts of water is toxic. When only a small quantity is to be used and the use is not continuous, only sufficient quantity for the actual work to be done should be purchased because of the danger of storing the surplus in broken packages. Unused solutions should be buried. Treated potatoes should be stored so that there is no possibility of their being mixed with potatoes for human consumption or of livestock eating them.

Acidulated Mercuric Chloride

To shorten the soaking time, the Minnesota Agricultural Experiment Station developed the so-called acid-mercury dip. It is prepared by adding enough hydrochloric acid to a 1 to 500 mercuric chloride solution to make a 1-percent solution. Tubers need to be soaked in this solution for only 5 minutes. Tests made in Oregon in 1932 and 1933 by the author showed that this method was practically as effective as the long-soak mercuric chloride treatment, but that it caused injury to the eyes and skin of the potato tubers in a number of cases, especially when they were not dried immediately after treatment. This method therefore cannot be recommended for general use until some consistent means of overcoming this danger is found.

In using acidulated mercuric chloride, observe the precautions recommended for mercuric chloride (above). **Strong hydrochloric acid is very caustic.**

Hot Formaldehyde

The hot-formaldehyde method is not quite so effective as the mercuric chloride one, but it may be used where the equipment is available. It is used widely in some places. The potatoes should be kept wet for 24 hours before treatment. The formaldehyde solution is made by dissolving 2 pints of formalin in 30 gallons of water heated to a temperature of 124° to 126° F. and held within these limits by steam or by means of a fire beneath the tank. The tubers are dipped for 4 minutes. A false bottom to the tank is necessary to keep the tubers at the bottom from becoming overheated. The solution should not be warmer than 126°, because above this temperature decrease in sprouting results; nor should it be cooler than 124°, as it would then not control the diseases

if the tubers are dipped for only the 4-minute period. To allow for condensation water when live steam is used for heating, 0.9 pint of formalin should be added after treatment of every 50 bushels of tubers. The solution does not lose its strength on standing if it is well covered, and it may safely be kept thus for a few days or weeks. Covering the tubers with a canvas or burlap for an hour after treatment adds to the efficiency of this method.

Formaldehyde is poisonous if used at full strength. Whether cold or hot it does not corrode metal. As diluted for use, it is not a dangerous poison.

Yellow Oxide of Mercury

Yellow oxide of mercury was first used for treating potatoes at the New York State (Geneva) Agricultural Experiment Station in 1929. It has been tested every year since then and found to be the best material for an instantaneous dip. Yellow oxide of mercury is as effective as mercuric chloride in the control of rhizoctonia canker. It is recommended for treating whole tubers. The best results are obtained if the tubers are planted within a few days after they are treated. If the time interval between treatment and planting exceeds 10 days, retarded vine growth and reduced yields will result.

Yellow oxide of mercury is very poisonous. The precautions recommended for mercuric chloride (p. 3) **should be used.**

One pound of yellow oxide of mercury (technical grade) is added to 30 gallons of water in a wooden container or a metal one painted with a good coat of asphaltum paint. This mixture is stirred vigorously with a wooden paddle until all the oxide is in suspension. A basket of seed potatoes is then dipped into the liquid, plunged up and down two or three times, and turned sidewise at the same time to insure complete wetting of the tubers and to keep the solution well stirred. The basket of treated potatoes is then removed and drained, and the tubers are dumped into a crate or open container to dry.

Additional mixtures may be added to the treating tub as needed. It is essential that this mixture be thoroughly stirred before it is poured into the treating tub so that the yellow oxide, which is heavy, will not settle. The mixture does not lose strength and can be used as long as any is left. Fifteen gallons will usually treat 100 bushels or more of seed potatoes.

For a time the yellow oxide of mercury treatment was very popular in New York; a few years ago the chemical was used to treat approximately 100,000 bushels of potatoes. Recently its use has declined somewhat as a result of the discovery that any mercury material, either added on treated seed or mixed with the fertilizer, tends to increase common scab in some sections with nonacid soils. This treatment, therefore, is not recommended in districts where the soil is alkaline enough to favor the development of common scab.

SUBERIZATION OF SEED PIECES

One of the major causes of rot of potato seed pieces is believed to be the improper healing (suberization, or corking over) of the cut surfaces. Omission of practices that would bring about healing is responsible for considerable rot of seed pieces in the field and at times

for complete crop failures. Improperly healed seed pieces that are not completely rotted before the eyes have had an opportunity to send out shoots may give rise to weak plants or to apparently normal ones. Later such plants may turn yellow and die prematurely. If the plants are still alive at digging time, they show the remnants of rotted seed pieces clinging to the underground stems and the interior of the stems is hollow and discolored. Tubers from such plants will give rise to healthy plants the following year, indicating that the trouble is not due to an organism carried over in the tuber.

Premature dying and occurrence of weak plants can be avoided to a large extent by planting whole tubers or by providing conditions for the proper corking over of the cut seed pieces. Suberization is a very simple process, but three conditions are necessary to assure the formation of a layer of cork cells over the cut surfaces. These conditions are the presence of air (oxygen), proper humidity, and proper temperature (60° to 70° F.). Under these conditions a protective layer of cork cells will develop over the exposed cut surface. This layer forms an effective barrier against decay organisms that may be present in the soil when the seed pieces are planted. If any one of these conditions is lacking, cork cells will not develop and the exposed cells will die. Shriveling of the seed piece may result or the surface may become dry and hard and later crack. When seed pieces without a protective layer of cork cells are planted, parasitic fungi and bacteria, which are usually present in the soil, may invade them and cause them to rot. Seed pieces may be planted immediately after being cut, however, provided the soil is not too wet or too dry and the weather is not too cold. Under such favorable conditions the seed pieces will suberize in the soil before the soil organisms have an opportunity to invade their tissues. When such conditions exist, special measures to bring about suberization before planting may not be necessary.

As the healing of cut seed pieces is very simple and inexpensive and the certainty of a perfect stand compensates so well for the little trouble involved, there is no valid reason why every grower should not suberize his seed pieces prior to planting, especially in districts where seed-piece rot is a problem. The writer has never found much seed-piece rot in fields where sound seed pieces were properly healed over before planting.

It may be necessary to modify slightly the method of suberization in different localities because of the variation in the air humidity. The freshly cut seed pieces may be placed in ordinary burlap bags that previously have been moistened in water. Care should be taken not to use bags that previously had contained fertilizer or salt, as these chemicals may cause burning of the seed pieces. Ordinarily the humidity within the bags is high enough to insure proper suberization of the seed pieces if they are kept in a protected building or shed. If the bags of seed pieces are stored where they dry out quickly, it may be necessary to sprinkle them occasionally or to cover them with a few additional moist bags. If the weather is cold, it may be necessary to heat the building artificially to 60° to 70° F. The bags of potato pieces should not be stacked too high, as this may exclude air. Under ideal conditions a protective layer of cork will develop within 48 hours.

Tests conducted in the United States and Canada have shown that when this method of healing is used application of land plaster or

sulfur to the seed pieces is not necessary. These substances may have some fungicidal value in preventing seed-piece rot if suberization is not practiced, but they are far less effective than suberization.

It should be remembered that the best cork formation is obtained by using sound tubers that have been kept under ideal storage conditions. Tubers that are beginning to shrivel and those from which the sprouts have been removed at various times do not suberize readily.

SPRAYING AND DUSTING

SPRAYING

In order to control some of the leaf diseases of potato, such as late blight, growers of table stock in some sections of the United States have to spray. Formerly a 10–10–100 bordeaux formula was used, but now a 10–5–100 formula is generally used in the Eastern States. This nearly neutral spray has given as good yields as those obtained with the formerly used alkaline spray or better yields. The materials required for making 10–5–100 bordeaux mixture are copper sulfate 10 pounds, lump lime 5 pounds (or hydrated lime 7 pounds), and 100 gallons of water. A convenient method of making up this spray mixture is to dissolve 10 pounds of pulverized copper sulfate in 50 gallons of water by suspending it in a sack near the top of the water overnight or in a small quantity of hot water and then making the solution up to 50 gallons; slake the 5 pounds of lump lime gradually in a small amount of water and dilute the milk of lime to 50 gallons (or mix the 7 pounds of hydrated lime in 50 gallons of water); then pour the two solutions together in a third barrel and stir vigorously. The resulting mixture (bordeaux mixture) has a milky-blue color. If it is impossible to spray at once, ½ ounce (2 heaping tablespoonfuls) of sugar dissolved in a small amount of water should be added to each 100 gallons of spray mixture. This will keep the spray mixture in good condition for a long time; otherwise, it would be worthless after about 24 hours.

Calcium arsenate or lead arsenate is added to the bordeaux mixture at the rate of 4 pounds to 100 gallons when needed to control Colorado potato beetles and flea beetles. In recent experiments 1 pound of actual DDT when added to 100 gallons of spray material has given striking control of flea beetles and very promising results for the control of some of the other potato-feeding insects.

In handling, mixing, and applying DDT, arsenates, and other harmful or poisonous insecticides, special care should be taken not to inhale excessive quantities at any time. Well-designed respirators affording protection to the entire face are available and should be used when such danger exists. After working with poisons the hands or any exposed parts of the body should be washed thoroughly.

To be effective, spraying must sometimes be started when the plants are 4 to 6 inches high and must be continued at regular intervals throughout the growing season. During some years and in some localities 5 or 6 applications are sufficient; under other conditions 10 to 12 applications are none too many. On the other hand, in some years spraying may not be necessary, at least not until late blight appears. As the spray programs may vary even in different parts of

the same State, the State agricultural college or the local extension service should be consulted about local practices.

It is a good practice to keep all new growth protected with the fungicide and to renew the application on the older growth. To give the vines a good protective coating, an application of 60 to 75 gallons to the acre is required when the plants are small and of 100 to 125 gallons when they are large.

Lime-sulfur sprays have given good results in controlling psyllids and flea beetles in some of the Western States, as discussed on page 43.

During World War II considerable research was conducted on new organic fungicides. Of these only Dithane with zinc sulfate and lime has been extensively tested in commercial fields under severe blight conditions. The results obtained in Dade County, Fla., showed Dithane plus tank-mix zinc-sulfate-hydrated-lime to be the most reliable fungicide thus far tested for the control of late and early blights provided the spray is thoroughly applied at intervals of not more than 8 days; it quickly loses its effectiveness after this interval. It is less injurious than bordeaux mixture, and plants sprayed with it significantly outyielded those sprayed with bordeaux. One of the drawbacks of this new fungicide is that it is fairly unstable, and the results obtained in different sections of the country are not always consistent. In some of the Northern States Dithane was not effective in controlling late blight. Other organic fungicides appear to be promising in certain sections of the country, but the information on their behavior is not yet sufficient to make general recommendations possible. Before using any of these, it is advisable to consult the State agricultural college officials as to whether they have been tested in the State.

DUSTING

Many growers prefer to apply copper-lime dust rather than bordeaux mixture for the control of foliage diseases. Dusting is more easily done than spraying and requires less expensive and less complicated machinery. Much experimental work in a number of States has demonstrated that a dust properly applied will give almost as good control of late blight as a spray. A very satisfactory dust for potatoes is a mixture of monohydrated copper sulfate and hydrated lime plus powdered lead arsenate or calcium arsenate when an arsenical poison is necessary to control insects. The materials must be so fine that 95 percent of the mixture will pass through a 200-mesh sieve. The percentages of copper sulfate used vary somewhat, but 20 percent is considered satisfactory. When an arsenical is needed, either 7 to 15 percent of lead arsenate or 10 to 25 percent of calcium arsenate replaces an equal percentage of the lime. It is also possible to purchase the dust already mixed. (**See warning,** p. 6.)

The amount of dust needed depends upon the size of the plants and the percentage of copper in the dust. The amount of copper is approximately the same as that found in the bordeaux mixture needed to give complete coverage. Generally the same number of applications of dust as of spray will be needed during the season. If the dust is applied when the leaves are dry, it is likely to be blown off. It is therefore desirable to apply it early in the morning when the leaves are covered with dew. When the copper-lime dust comes in contact with moisture on the leaf, the particles of copper sulfate and lime combine to form a bordeaux mixture.

Dusting is often done on peat land, where it is frequently impossible to operate heavy sprayers. Also on hilly land or where it is difficult to get water to operate sprayers, dusting is often preferable.

DISEASE-RESISTANT VARIETIES

One of the most effective means of combating potato diseases is the use of varieties that are resistant to one or more diseases. In recent years the production of such varieties has been given much consideration in the United States and elsewhere. This work has been emphasized especially in the national potato-breeding program, which is conducted cooperatively by State agricultural experiment stations and the United States Department of Agriculture. None of the varieties so far produced is resistant to all diseases, but work is now in progress leading to the combination of as many of the characters for resistance as possible in a single variety.

No variety that will meet the needs of all the States has been distributed, and probably such an ideal potato will not be produced in the immediate future. There is, however, a demand from some sections for each one of the new varieties distributed because their special characters, such as resistance to certain diseases, give them definite advantages over the old varieties.

Among the new varieties distributed under the national potato-breeding program, Earlaine, Katahdin, Chippewa, Houma, Sebago, Sequoia, and Mohawk are resistant to mild mosaic. Katahdin, Chippewa, and Houma are resistant also to net necrosis; Katahdin and Houma are somewhat resistant to leaf roll. Sebago is moderately resistant to late blight, common scab, and yellow dwarf. Sequoia is somewhat resistant to late blight and to leafhopper and flea beetle injury. Menominee, Ontario, Cayuga, and Seneca are resistant to common scab; these new varieties are not yet widely grown, but one of them might be found satisfactory under conditions where common scab is becoming a limiting factor in potato production. Another new variety, Teton, is highly resistant to ring rot. Resistance to latent mosaic and rugose mosaic has been found in a number of seedling varieties now under test, but not in those now available to growers.

The State agricultural colleges will be able to advise growers regarding the disease-resistant varieties best adapted to local conditions as demonstrated by tests.

STORAGE

The primary purpose of storage is to protect a more or less perishable fruit or vegetable product from freezing or injurious chilling and from overheating. To keep storage and transit diseases in check attention must be given to proper ventilation, humidity, and temperature. Stored potatoes need thorough circulation of air, and the air should not be so dry as to cause an excessive shrinkage of tubers, which weakens their vitality and resistance to decay. Poor aeration may cause blackheart. The best temperature for the storage of potatoes is between 36° and 40° F. Adequate ventilation and humidity and the right temperature are attained by proper construction and management of storage houses, as described in Farmers' Bulletin 1986, Potato Storage.

DISEASES DUE TO PARASITES

The parasites that cause diseases of potatoes are fungi, bacteria, and nematodes. Considerable injury to potatoes may also be caused by leafhoppers and flea beetles. Diseases due to parasites can often be controlled or prevented by the use of seed treatments and sprays. Growers of table potatoes should therefore use the various control measures recommended to reduce the losses from attacks by parasites.

BLACKLEG

Blackleg, caused by *Erwinia phytophthora* (Appel) Bergey et al., is a bacterial disease. In some years it is responsible for heavy losses in some potato-growing sections.

FIGURE 1.—Potato plant showing blackleg infection. Note the blackening of the lower part of the stem and the formation of aerial tubers (*a*). (By courtesy of the Minnesota Agricultural Experiment Station.)

In the plants the disease can be recognized by the rolling of the upper leaves of one or more shoots and the gradual yellowing of the foliage, finally of all the leaves. At the base of the stem mushy, inky-black lesions develop (fig. 1). Under dry conditions only the pith in the top of the plant may show blackening, and aerial tubers (enlarged buds) may form on the stems.

As a rule, rot begins at the stolon end of the tuber. On the outside a small amount of rot or often only a small, circular, black opening is

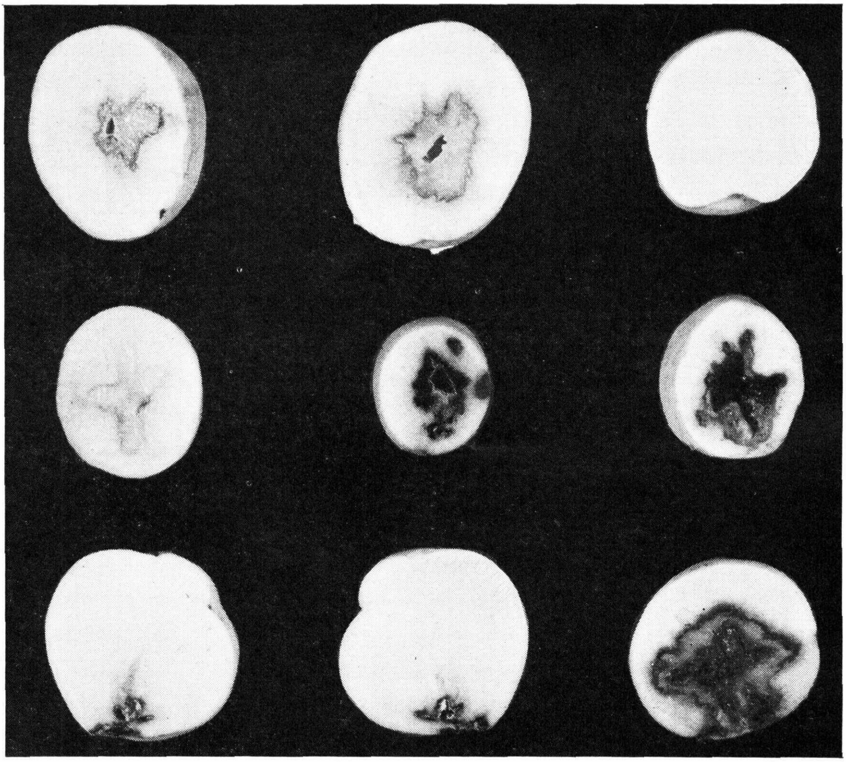

FIGURE 2.—Potato tubers sliced lengthwise to show early and advanced stages of blackleg infection.

visible. In the interior of the tuber a progressive decayed area develops into an irregular, black, soft or slimy hollow.

If sufficient moisture and fairly high temperatures prevail, the disease progresses rapidly and the entire plant wilts and dies. Many of the tubers from such plants will be rotten at digging time (fig. 2). In storage tuber rot may be serious.

Recommendations for Control

To avoid blackleg, only disease-free tubers should be planted. If cut seed is used, it should be well suberized.

BACTERIAL SOFT ROT

Bacterial soft rot, caused by *Erwinia carotovora* (L. R. Jones) Holland, is a serious disease, especially in some of the Southern States. It may be responsible for heavy losses.

Affected tissues of tubers are typically white to cream-colored, soft, and somewhat watery especially if the decay develops in a moist atmosphere. A clear, amber-colored liquid often exudes from the decayed part under these conditions. The decayed part develops a brown color, which begins at the margin and may gradually extend over the entire surface after exposure to air and light. The affected tissues lose their soft, watery consistency in a dry atmosphere. As they dry, they may become slimy; when not completely dry they consist of a grayish-white chalky mass. In advanced stages the disease is generally accompanied by infection by secondary organisms.

The bacterial soft rot organism is found in the soil; its relative abundance depends mainly on the supply of moisture and dead plant material. In the field infection of tubers may start in fresh breaks, cracks, bruises, and lenticels and in lesions caused by other organisms.

The disease may spread by contact from decayed to healthy tubers that are packed or piled together. The practice of washing potatoes before shipment has become rather general during recent years, especially in the South; although this greatly improves the appearance, it often increases the amount of decay. Early potatoes are usually somewhat immature and have tender skins; during packing and handling a certain amount of bruising is practically unavoidable. During washing, potatoes are exposed to infection from wash water containing decay organisms that may be brought in with the soil or on tubers already infected in the field. Every skin break in the tubers is a potential point of entry for the decay organism. In a season favorable for rot development 50 to 75 percent of the tubers in a shipment may develop decay.

Recommendations for Control

Since development of bacterial soft rot in transit or storage is increased by washing the tubers and crating them while wet, it is desirable to dry the tuber surfaces rapidly before or after packing in crates. Experiments with heated air have shown that washed potatoes may be dried without damage for 4 minutes in air heated to 150° F. and that this will control the disease in storage and transit. Drying washed potatoes before packaging by means of hot-air driers has been carried out on a commercial scale. Results in Florida have shown that bacterial soft rot failed to develop sufficiently to cause rejection of a single shipment that had been predried. In controlling the disease every effort should also be made to reduce to a minimum the mechanical injury of the potatoes.

RING ROT

Ring rot, caused by *Corynebacterium sepedonicum* (Spieck. and Kotth.) Skapt. and Burk., is a very infectious bacterial wilt and ring rot. It has been noted in this country only since about 1934, but it is now present in nearly all potato-growing States.

The symptoms of ring rot generally do not show until the plant is nearly full grown. One or more stems in a hill may wilt and may be

more or less stunted, and the remainder may seem normal. The areas between the veins of some of the lower leaves of the infected stems become pale yellowish at first, and within a few days a more pronounced yellowing of these areas, together with an upward rolling of the leaf margins, develops. Leaf discoloration is accompanied by a progressive wilting (fig. 3), which continues until all the leaves of the stem are wilted. After that the stem soon dies. If the stem of a plant in the advanced stages of the disease is cut across at the base and squeezed, a creamy exudate is expelled.

Infection of the tubers takes place at the stem end and progresses through the vascular tissue. At the stem end infected tubers will show a cheesy rot, which is creamy yellow or light brown in the region of the vascular ring. When pressure is applied in sufficiently advanced cases, there will be a definite separation of the tissue outside of the vascular ring from the tissue on the inside (fig. 4).

Recommendations for Control

The only practical control for ring rot is to plant disease-free seed. Since tubers can be infected by the ring rot organism without show-

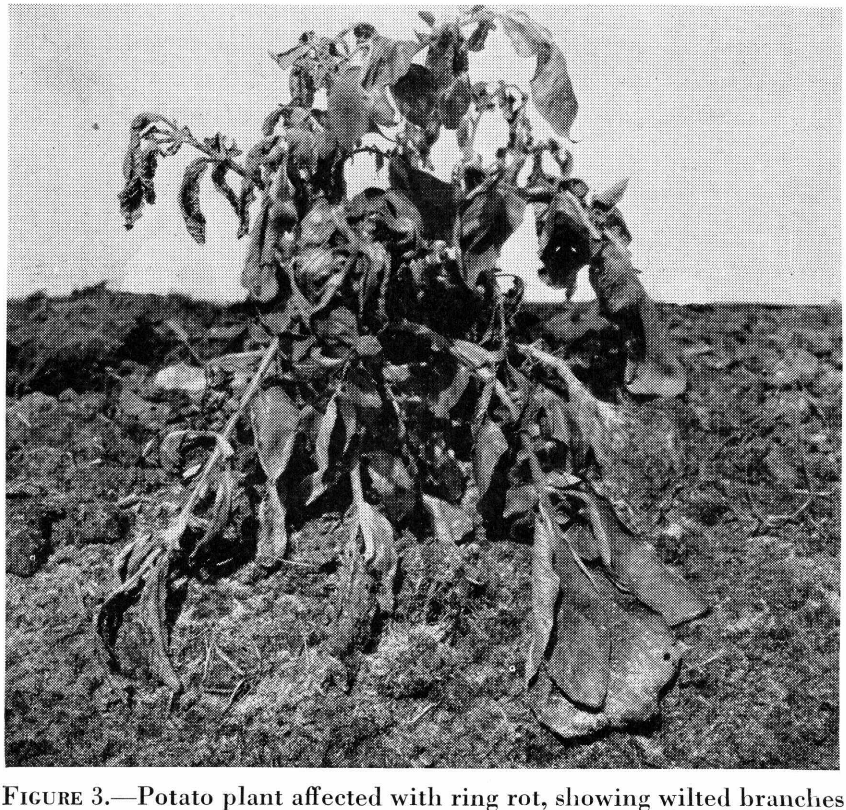

FIGURE 3.—Potato plant affected with ring rot, showing wilted branches and leaves. (By courtesy of the Florida Agricultural Experiment Station.)

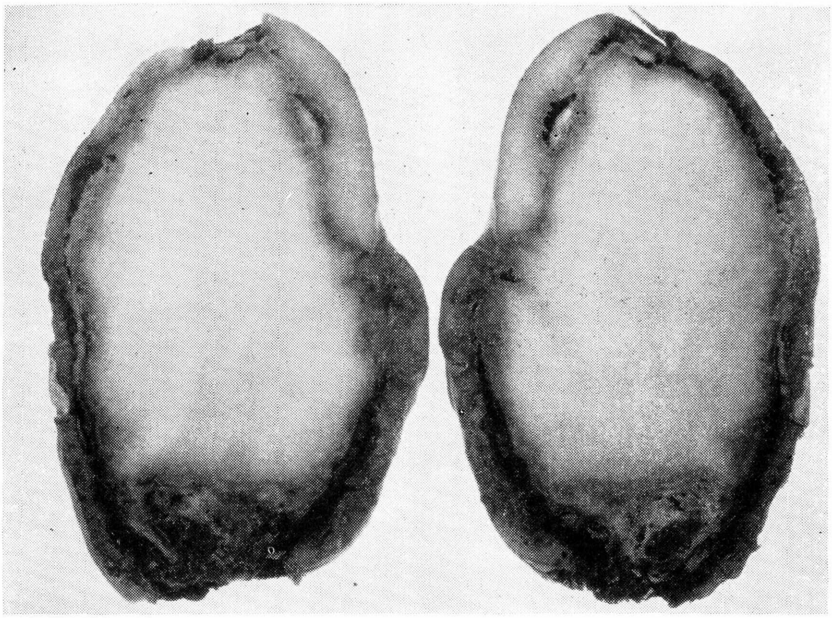

FIGURE 4.—Potato tuber affected with ring rot, sliced lengthwise to show the extent of decay and the separation of the cortex tissue from the core of the tuber. (By courtesy of the Florida Agricultural Experiment Station.)

ing symptoms, diseased tubers cannot all be discarded by examining the seed tubers at planting time.

As ring rot is highly infectious, a knife that has been used to cut an infected tuber may infect the next 20 seed pieces cut with it. It is possible to disinfect the knife by inserting it momentarily in a solution of mercuric chloride (1 part to 1,000 parts of water) or for 10 seconds in boiling water. Use has been made of a rotary knife made from an 8-inch rotary saw blade with the teeth ground off and sharpened. The blade is mounted in such a manner that the bottom half of it runs in a bath of a good disinfecting solution such as mercuric chloride (1 part to 500 parts of water, or 4 ounces to 15 gallons of water). The blade should be revolved slowly so as to cut each potato with a newly disinfected part of the blade. The turning of the blade may be accomplished by means of an electric motor (fig. 5).

Equipment, such as graders, planters, diggers, and baskets, that has been used for handling potatoes infected with ring rot should be disinfected with copper sulfate (1 pound to 10 gallons of water).

Before the new crop of seed is placed in storage where ring rot was present the previous year, the storage cellar should be cleaned out completely by burning any old tubers and debris that remain in the storage. After being well cleaned, the storage quarters should be sprayed with copper sulfate (1 pound to 10 gallons of water) to kill any ring rot bacteria that may be present.

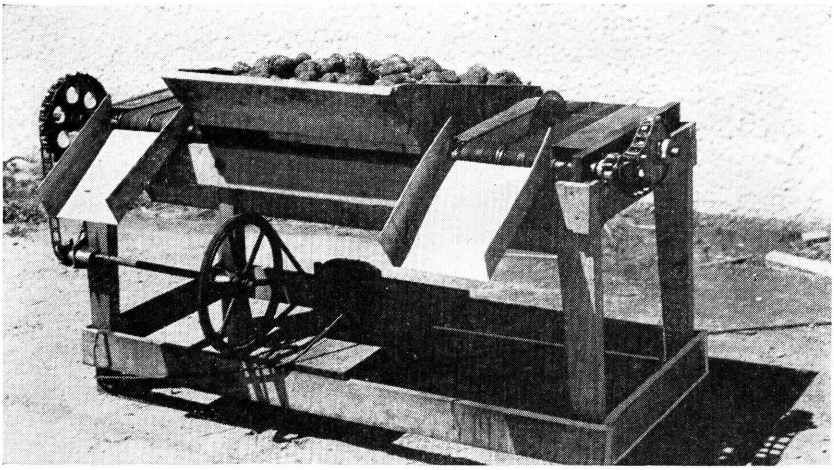

FIGURE 5.—A rotary knife mounted in such a manner that the bottom half of it runs in a bath of a disinfecting solution. (By courtesy of the Wyoming Agricultural Experiment Station.)

BROWN ROT (BACTERIAL WILT)

Brown rot, caused by *Bacterium solanacearum* E. F. Sm., is also known as bacterial wilt and southern bacterial wilt. Climatic conditions limit the common occurrence of brown rot in the United States to localities in the South Atlantic and Gulf Coast States from Maryland to Texas and in Ohio, Illinois, and Kentucky. It differs in this respect from ring rot (p. 11), as climatic conditions apparently do not limit the distribution of that disease.

The first symptom of brown rot in the potato plant is a slight wilting of the leaves at the ends of the branches during the hottest part of the day. Affected plants recover during the night, but the wilting becomes more pronounced each day until finally the plants die. The vascular bundles in the stems, roots, and stolons turn brown when they become clogged with bacteria; this clogging causes the wilting and death by cutting off the water supply of the plant. The brown color is finally evident on the outer surface of these parts and may be seen on the stem of severely affected plants 1 inch or more above the soil line. When the vascular bundles of the affected parts are cut or broken, the bacteria ooze from them as a white slimy mass.

In the tuber the vascular area is invaded first by the bacteria; when the disease has developed to a certain stage the brown color of the affected tissues near the surface can be seen, particularly around the stem and eyes. The bacterial ooze exudes from the eyes and stem end of the severely diseased tuber and may become mixed with dirt, which sticks to the surface of the tuber when dried (fig. 6). Tubers left in the ground continue to decay; the bacteria destroy the tissue that surrounds the vascular ring and finally break through the skin. Other rot organisms enter the tuber at this stage and assist in making it a slimy mass with an offensive odor.

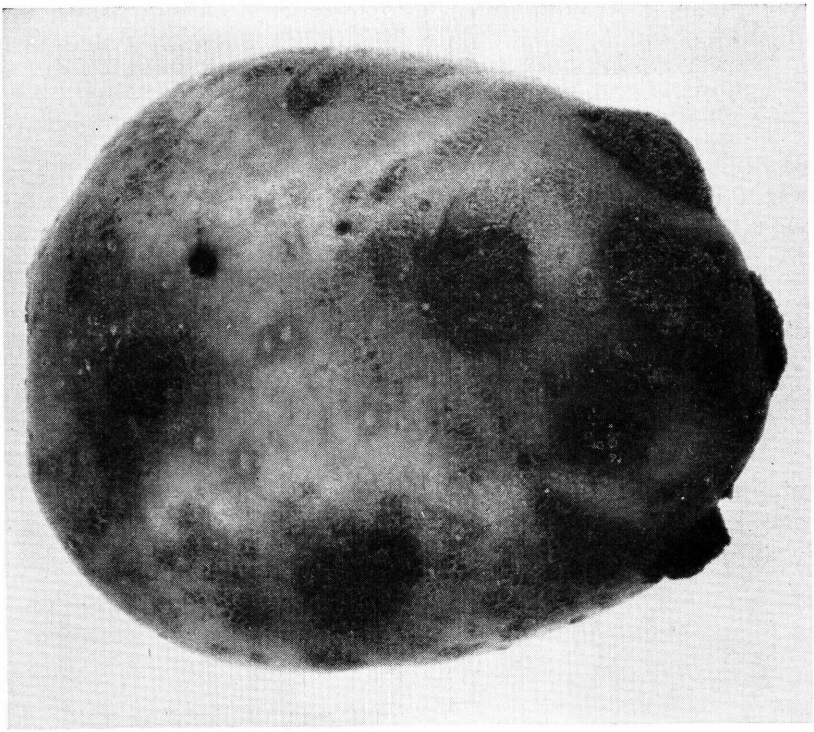

FIGURE 6.—**Spaulding Rose potato tuber affected with brown rot. Note bacterial exudate and dirt sticking to the eyes. (By courtesy of the Florida Agricultural Experiment Station.)**

Plants with their tops killed by brown rot may bear healthy as well as diseased tubers. Also plants showing no signs of the disease in their tops may sometimes produce diseased tubers.

Recommendations for Control

The Katahdin and Sebago varieties are much more resistant to brown rot than the Spaulding Rose, Irish Cobbler, and Triumph. As seed potatoes used in most sections of the United States are produced in localities where brown rot does not occur, they usually do not carry this disease. Because so many weeds are hosts of *Bacterium solanacearum*, it would be impracticable to attempt to eliminate brown rot from potato land by crop rotation or weed eradication.

Experiments in Florida have shown that in sandy soil brown rot can be controlled by an application of 800 pounds of sulfur to the acre in the summer, followed by 3,000 pounds of limestone to the acre in the fall. This treatment is not recommended on muck, peat, loam, or clay.

LEAK

Leak, a tuber rot caused by *Pythium ultimum* Trow, is serious in some years on potatoes that are harvested and moved during extremely warm weather; the early crop of Idaho and Washington and the crop

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grown in the upper San Joaquin Valley of California are examples. The disease may be serious there but it has not been common during the last few years, perhaps because of better handling of the crop. In other sections it seems to occur only if there is abnormally warm weather during digging, moving, and early storage of the crop.

The most characteristic symptom of leak is the extremely watery nature of the affected tissues. The water usually is held by the disintegrated tissues, but when pressure is applied a yellowish to brown liquid is given off readily. Another characteristic symptom is the granular nature of the diseased tissues. Externally the affected tissues appear turgid and may show discoloration ranging from a metallic gray in the red varieties to brown shades in the white- and dark-skinned ones. Internally the affected tissues are creamy at first; upon cutting, as well as in the later stages of the disease, they soon turn tan or slightly reddish and then brown and finally inky black. The diseased areas generally are sharply set off from the healthy tissue. Rarely there is discernible an external or internal fungus growth; the cavities caused by the fungus are not lined by white or brightly colored molds as in the soft types of fusarium rot, which resemble leak. The colors of tissues affected with leak resemble those of blackheart-affected tissues, but the latter do not become soft, watery, and granular.

Tubers become contaminated in the field, where the causal fungus lives in the soil. Infection takes place during hot weather and apparently only through wounds, which may not be visible. Leak frequently is found in tubers affected with sunburn and sunscald, especially in tubers allowed to lie in or on hot soils after being dug. At temperatures between 60° and 90° F. lesions become visible within 36 hours after infection. At temperatures above 50° leak lesions usually are invaded by bacteria, which check the growth of the leak organism and produce foul-smelling, sticky or slimy decays.

Recommendations for Control

Control of leak involves keeping the tubers as cool and dry as possible during harvesting and loading as well as in the early stages of transit and storage and avoiding injury to the skin.

SCLEROTIUM ROT (SOUTHERN BLIGHT)

Sclerotium rot (southern blight), caused by *Sclerotium rolfsii* Sacc., is a disease of various truck crops in the southern part of the United States. It attacks potato vines in the field and produces a rapid decay of the stems at the surface of the ground. If conditions are favorable, it also produces a very rapid rot of tubers. This rot is white and almost odorless in the first stages, but it takes on a yellowish color later. In mild cases there are only slightly sunken spots; the soft, decaying material of such spots can be separated easily from the healthy by pressure. In severe cases the entire contents of the tuber are turned into a liquid. The surface of the decaying potato is covered with fine fungus threads and hard, round sclerotia (seedlike bodies resembling mustard seed) (figs. 7 and 8). When scattered in the soil, they germinate under favorable conditions and infect new crops.

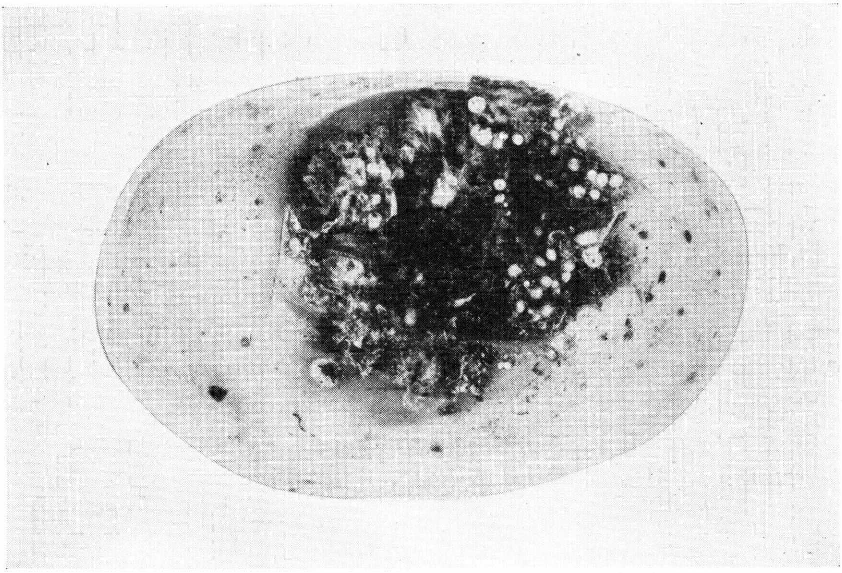

FIGURE 7.—Potato tuber rotted by *Sclerotium rolfsii* at stem end. Note sclerotia of the causal fungus on the dirt clinging to the affected tissue. (By courtesy of the Florida Agricultural Experiment Station.)

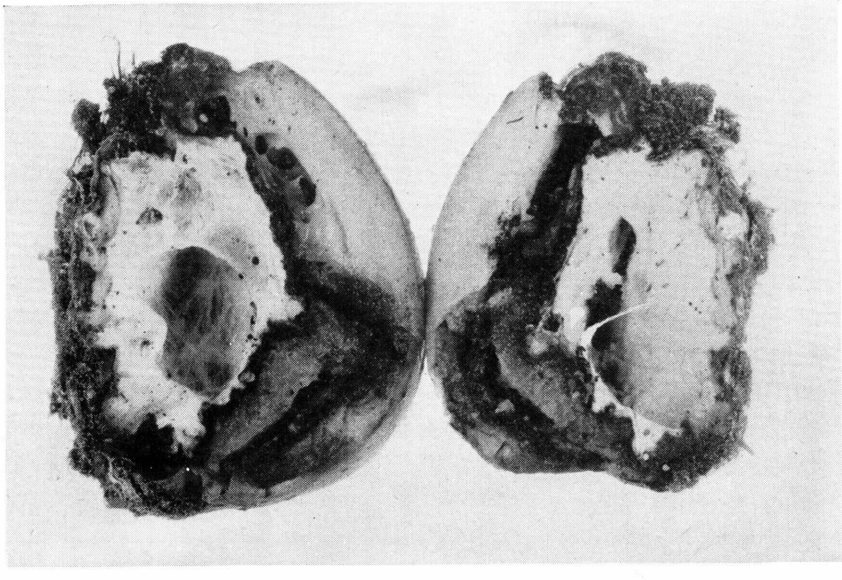

FIGURE 8.—The potato tuber shown in figure 7, sectioned to show the rot caused by *Sclerotium rolfsii* and its mycelium in the decayed area. (By courtesy of the Florida Agricultural Experiment Station.)

Recommendations for Control

No practicable way to exterminate the sclerotium rot fungus from the soil is known. Destruction of diseased plants in the field should be practiced in order to reduce the amount of soil infection. When storage of the early southern potatoes is necessary, low temperature in storage will check the development of the decay.

JELLY-END ROT

Jelly-end rot, caused by *Fusarium* sp. and other organisms, gives the affected parts of potato tubers a jellylike consistency. Long potatoes like Burbank and Russet Burbank, grown especially on the Pacific coast, are subject to this disease. At harvesttime the rot varies widely in type and extent; it ranges from a slight withering to a dry, wrinkled, sunken, and rather tough condition and the discoloration from none to light brown or black, involving half an inch or more of the tuber. At times there is a soft and rather jellylike light-brown rot extending as much as 1½ inches from the stem end and the rest of the tuber is sound and unaffected (fig. 9). In storage the diseased tubers often do not rot further unless the conditions are unfavorable. The affected tissues frequently dry down, forming a sharp line of demarcation between the sound and the healthy tissues. The exact conditions leading to the development of the rot are not known, but it seems possible that when soil moisture is deficient late in the growing season the plant may actually withdraw water from the stem end of the tuber. This brings about a sunken, withered condition favorable for the entrance of both saprophytic and parasitic organisms, and rot soon follows. No organism is found consistently associated with the disease, and the rot develops in the crop without any apparent relation to the condition of the seed potatoes at planting time.

Recommendations for Control

No special measures for the control of jelly-end rot can be recommended. However, the rot can doubtless be avoided to a considerable extent by the maintenance of a uniform and adequate supply of moisture in the soil throughout the season.

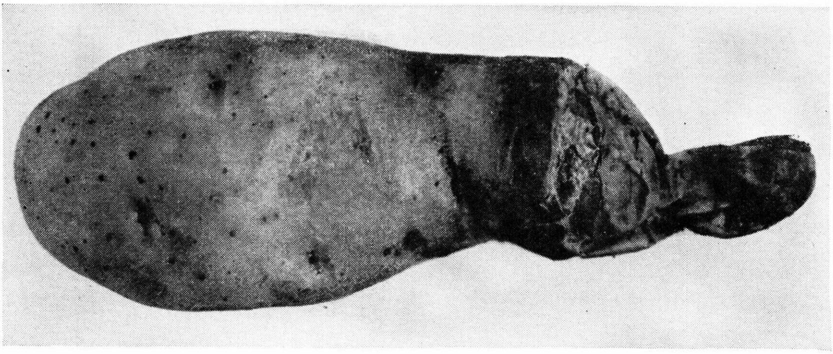

FIGURE 9.—Pointed-end Russet Burbank potato tuber affected with jelly-end rot.

Wart, caused by *Synchytrium endobioticum* (Schilb.) Perc., was introduced into eastern North America about 1912. Now it is found only in limited districts in Pennsylvania, Maryland, and West Virginia, where it is confined mostly to small gardens. For many years

FIGURE 10.—Underground stem of a potato plant showing severe wart infection.

it has caused serious damage in Europe, especially in certain districts of England and Ireland.

The disease is characterized by warty outgrowths on the underground parts of the plant. These outgrowths vary greatly in size (fig. 10). Sometimes the entire tuber is converted into a spongy, warty mass. The warts occur abundantly on the tubers, stolons, and underground part of the main stem. When this wart-affected tissue

is left in the soil, it soon becomes broken up and liberates millions of spores, leaving the land badly infested for years.

Experiments carried on in Pennsylvania have shown that when wart-infested soil is kept in sod the organism may remain active in the soil for over 20 years. If the soil is planted with nonsusceptible crops and is cultivated regularly, the organism gradually disappears from the soil in 10 years or even less. A thorough eradication program is now being conducted by the Pennsylvania Department of Agriculture. Infested soil is treated with ammonium thiocyanate at the rate of 2,000 pounds per acre or with flaked copper sulfate at the rate of 2,500 pounds per acre. Treated gardens are then planted with susceptible potato varieties, and each tuber is thoroughly examined at digging time for the presence of wart. If during a period of 5 years wart fails to develop in treated plots, it is assumed that the wart has been completely eradicated. It is believed that by carrying on a thorough eradication program, eventually wart will be entirely eliminated from Pennsylvania.

The potato, the nightshade (*Solanum nigrum* L.), the true bittersweet (*S. dulcamara* L.), and under some conditions the tomato are the only plants known to be attacked by wart.

Recommendations for Control

The chief and most reliable means of controlling potato wart is the use of wart-immune varieties of potatoes, such as Spaulding Rose, Green Mountain, Irish Cobbler, and Burbank.

COMMON SCAB

Common scab, caused by *Actinomyces scabies* (Thaxt.) Güss., is known to exist in every potato-growing section of the United States. It is confined entirely to the tubers. Usually the spots are small and brownish at first, but later they enlarge. The lesions may be large and very corky; frequently they extend below the tuber surface and

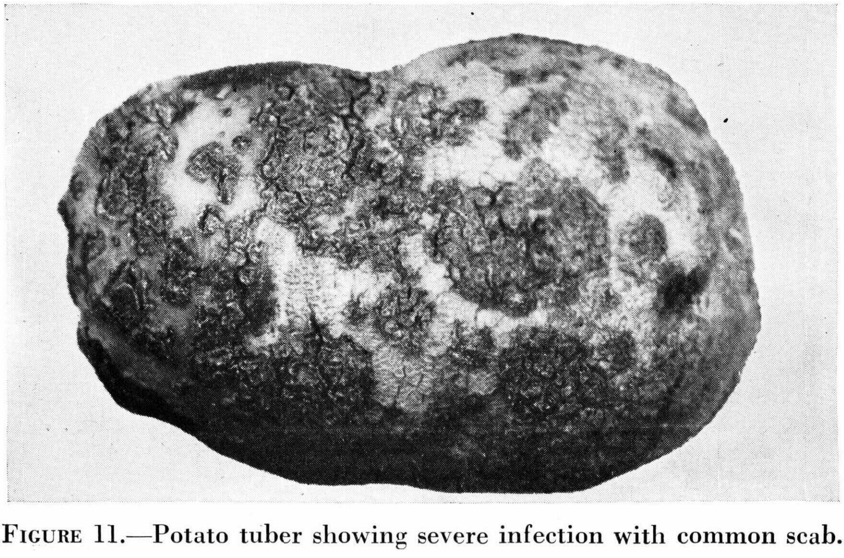

FIGURE 11.—Potato tuber showing severe infection with common scab.

leave deep pits when the corky tissue is removed. Such lesions are known as the pitted type of scab. Sometimes the lesions appear as small russeted areas so numerous that they almost cover the tuber surface, or they may be slight protuberances with depressed centers. These lesions are covered with a small amount of corky tissue. This type of lesion is known as surface scab (fig. 11).

Common scab lesions are sometimes confused with abnormally enlarged lenticels. Flea beetle injury, caused by the larvae of three species of flea beetles (*Epitrix cucumeris* (Harr.), *E. subcrinita* (Lec.), and *E. tuberis* Gent.), may also in some cases resemble the external appearance of the first stages of common scab infection. However, when the pustules or furrows made by the flea beetle larvae are cut through, tough splinters of corky tissue are found extending perpendicularly into the tuber. Not infrequently such furrows are secondarily infected with the rhizoctonia canker and common scab organisms; such infections deepen the furrows and the insect-feeding scars. White grub and rodent injuries lead to the formation of large cavities that are seldom confused with common scab. These cavities are free from the heavy cork incrustations that are characteristic of both the deep and the shallow form of common scab.

Common scab is particularly severe in alkaline soils above pH 7[2] or in soils that are about neutral, but it causes little or no damage in strongly acid soils. Applications of fresh manure should not be made just before the field is plowed for potatoes, because such a procedure seems to stimulate development of common scab. Likewise, applications of lime or wood ashes tend to bring about an alkaline condition favoring scab. In some of the Pacific Coast States common scab develops most when the soil moisture is slightly below the requirement for optimum growth of the potato plant. If the soil is of such texture that there is abundant aeration, however, scab may develop readily even though the soil is very wet.

Recommendations for Control

The common scab organism can be carried from one season to another in the scabby spots on the tubers; therefore, seed treatment appears to be the most important means of control. Seed treatment has not been uniformly successful, however, in controlling scab in the succeeding crop, chiefly because the scab organism can live in the soil for a long time, especially if the soil is alkaline. If the soil is heavily infested, the use of clean or disinfected seed will be of little value in preventing scab from developing on the new tubers. If the soil is acid, scab generally fails to develop even if badly infected seed is planted. Attempts to make alkaline soil acid by the application of sulfur at the rate of 300 to 600 pounds per acre have been most successful on the lighter types of soils, but even on these the control of scab has not yet been entirely satisfactory; the use of sulfur has generally reduced somewhat the severity of scab.

[2] The "pH value" is the most common term now used to express the degree of acidity or alkalinity. It is simply a numerical expression denoting the acidity or the alkalinity. A neutral soil has a pH value of 7; values above 7 denote alkalinity and those below 7 acidity. A soil with a pH value of 6 is mildly acid and one with a pH value of 4 very strongly acid.

The development and use of scab-resistant varieties appear to provide the best future possibility of successfully growing potatoes on scab-infested land. Considerable progress is being made by the United States Department of Agriculture and the State agricultural experiment stations in developing varieties highly resistant to common scab. Menominee, Ontario, Cayuga, and Seneca have already been introduced as commercial varieties highly resistant to scab.

POWDERY SCAB

Powdery scab, caused by *Spongospora subterranea* (Wallr.) Lagh., is confined to the tuber and is limited to moist, cool regions. It has been found in a number of States from Maine to Minnesota and also in the coast counties of Oregon. The disease does not develop when the temperature is very high. So far it has not proved such a serious menace to the national potato industry in the United States as was at first feared.

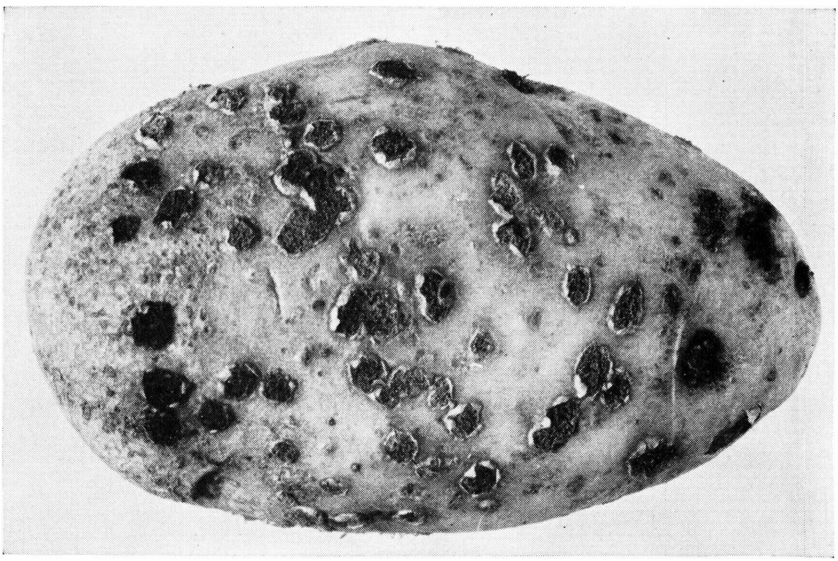

FIGURE 12.—Potato tuber showing the mature stage of powdery scab.

The disease resembles common scab somewhat, but the individual spots are more nearly circular and, as a rule, they are smaller in diameter. When fully mature the open pustules are filled with a brown more or less powdery mass of spores and broken-down tissue and are surrounded by fringed remnants of the skin (fig. 12). In the immature stages these spots are closed and somewhat raised and are dark on the outside and brown or olive brown on the inside. The causal fungus lives in the soil, and infection takes place during the growth of the tubers. Under some conditions the diseased seed tubers may introduce powdery scab into clean soils.

Recommendations for Control

Powdery scab is not satisfactorily controlled by seed treatment. Affected tubers should not be used for seed purposes in localities with cool, moist climates. Long rotations are necessary to rid the soil of the organism when it once becomes established.

RHIZOCTONIA CANKER (BLACK SCURF)

Rhizoctonia canker (black scurf), caused by *Rhizoctonia solani* Kuehn, is perhaps the commonest potato disease in the country, being present in every potato-growing section.

On potato tubers the fungus develops into small brownish-black bodies closely adhering to the skin (fig. 13). They may be as small as a pinhead or as large as a half pea. These bodies, known as sclerotia,

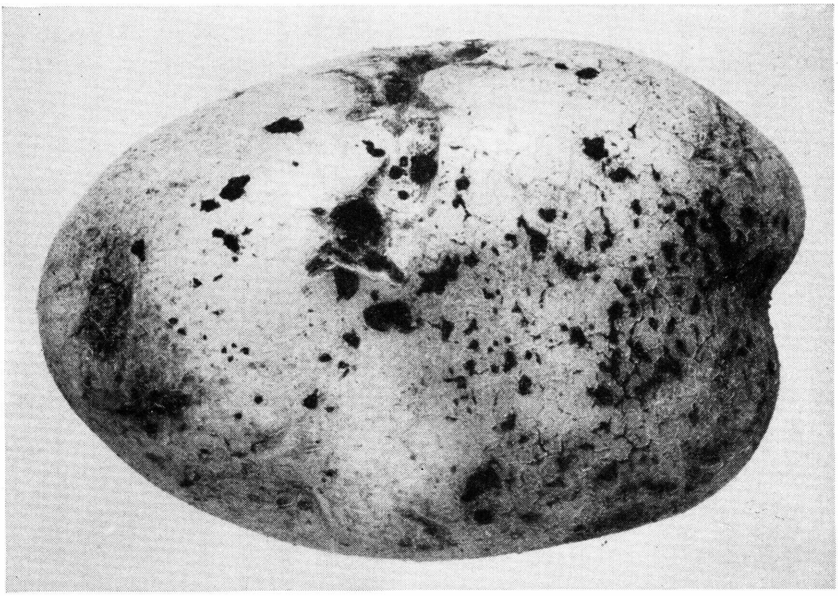

FIGURE 13.—Potato tuber affected with rhizoctonia canker. Note the brownish-black sclerotia.

are composed of a very compact weft of mycelial threads and represent the resting stages of the fungus. When introduced into the soil on seed tubers, these sclerotia produce an abundance of fungus threads that attack the young shoots, roots, stolons, and tubers of the new crop. Often the sprouts are attacked and killed by the fungus before they reach the surface of the ground. This may lead to the production of new sprouts that in turn have their tips killed, with the result that there is formed a rosette, or cluster, of sprouts, none of which reach the surface of the ground.

In a field where sclerotia are introduced there may be vigorous, healthy-looking plants; others that are only half as tall; some that are weak and spindling; and many misses. Cankers may occur on the sto-

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lons, cutting the tubers from the main stem and thus preventing their further development. Cankers occasionally develop on the stems of older plants, but they do not extend so deep into the interior as to destroy the parts above. These cankers show at or below the surface of the soil as irregular, elongated brown areas (fig. 14). Such cankers

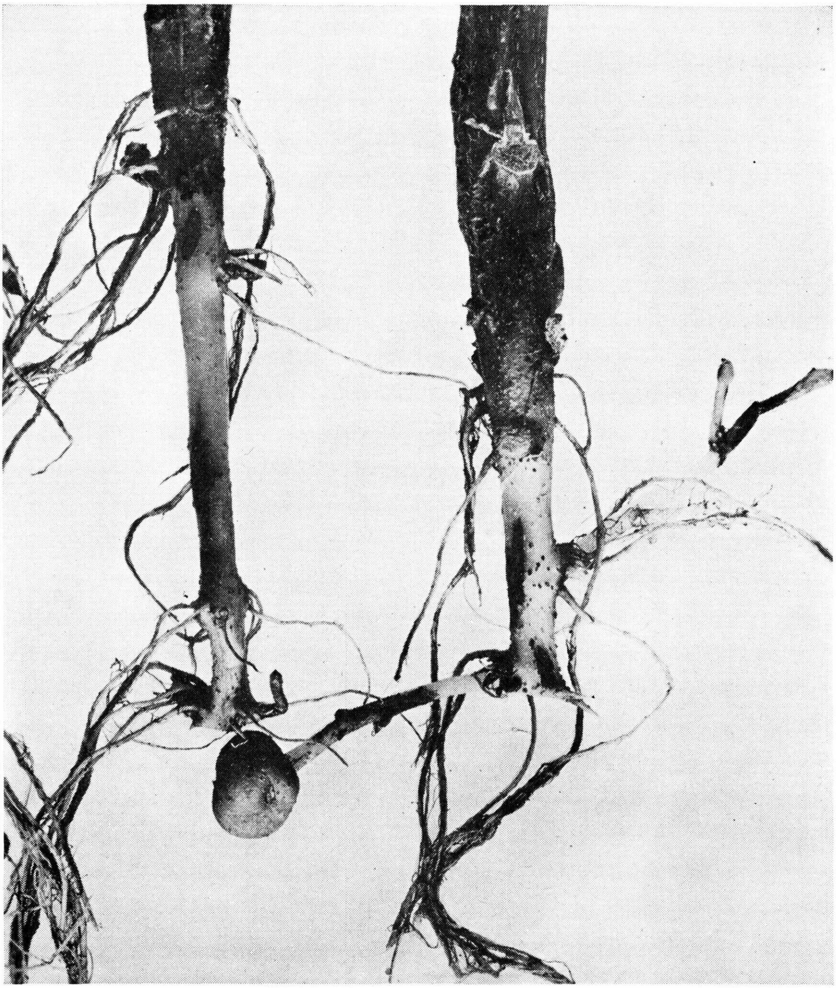

FIGURE 14.—Potato stalks, roots, and stolons showing brown, dead, cankerous areas caused by *Rhizoctonia*. Sometimes the stalks may be completely girdled.

interfere with the movement of the elaborated food material to the roots and tubers and thus suppress their normal development. The vines become yellow or reddish yellow; the leaves have a tendency to roll because of the accumulation of food above the canker; the stalks become swollen, especially at the nodes; and the buds enlarge sometimes to the size of small tubers, giving rise to the term "aerial tubers." This term is also applied to numerous small, irregular tubers produced

on short stolons at the surface of the ground when cankers on the main stem or on the stolons below ground prevent normal tuber formation.

The skin of infected tubers may become russeted, sometimes badly so; the appearance is not greatly unlike that caused by common scab. The roughening of the skin may be local or over the entire tuber and slight to very pronounced. This type of russeting, which is sometimes referred to as russet scab, is common in severely infested fields, particularly if the soil is heavy and poorly drained.

The causal fungus is able to live as a saprophyte for a long time even in dry soil. If the environment is favorable, infection takes place when the host is planted. Sclerotia of the fungus are also able to live from season to season on perennial plants. They carry the fungus over winter and disseminate it. In the spring, when the soil becomes warm and moist, sclerotia found in the soil and those adhering to the potato tubers develop a white moldy growth. When these filaments come in contact with the sprouts or the stolons of potatoes, they penetrate the tissues and produce the brown cankers already described. Although greatest injury to the sprouts occurs at temperatures below 70° F., cankers may be produced at any temperature from 48° to 80° if other conditions are favorable for growth of the fungus.

Recommendations for Control

Since *Rhizoctonia* is able to live over in the soil and its sclerotia can overwinter on the surface of tubers, both of these facts must be considered in undertaking the control of rhizoctonia canker. Since in addition to potatoes many other cultivated plants and weeds are susceptible to this fungus, crop rotation is not always as effective in eradicating it as might be expected. Planting only tubers free from *Rhizoctonia* infection or treating slightly affected seed tubers with mercuric chloride or other disinfectants as described on page 2, combined with crop rotation, provides the best method of control.

WILTS

Potato wilts may be caused by *Verticillium albo-atrum* Reinke and Berth. and certain species of *Fusarium* (*F. oxysporum* Schlecht., *F. eumartii* Carpenter, *F. solani* (Mart.) Appel and Wr., and *F. avenaceum* (Fr.) Sacc.). *Verticillium albo-atrum* is often responsible for wilt in the northern sections, but it does not attack plants at relatively high temperatures.

The symptoms caused by *Fusarium oxysporum* and *Verticillium albo-atrum* are so similar that they may be treated together. Attacked plants may wilt rather suddenly and die in a comparatively short time, or they may show the effects slowly and succumb very gradually (fig. 15). Plants produced from infected tubers may be stunted from the beginning and die without reaching average size. Such vines, which have a more spindling growth than healthy ones, are yellowish green. Also there may be some curling and rolling of the leaflets and tip burning. Such vines die prematurely, but the stalk remains upright except for the tips, which may droop. Vines from healthy tubers that contract the disease from neighboring plants or from the soil show the first indication of the disease in the yellowing and drooping of the

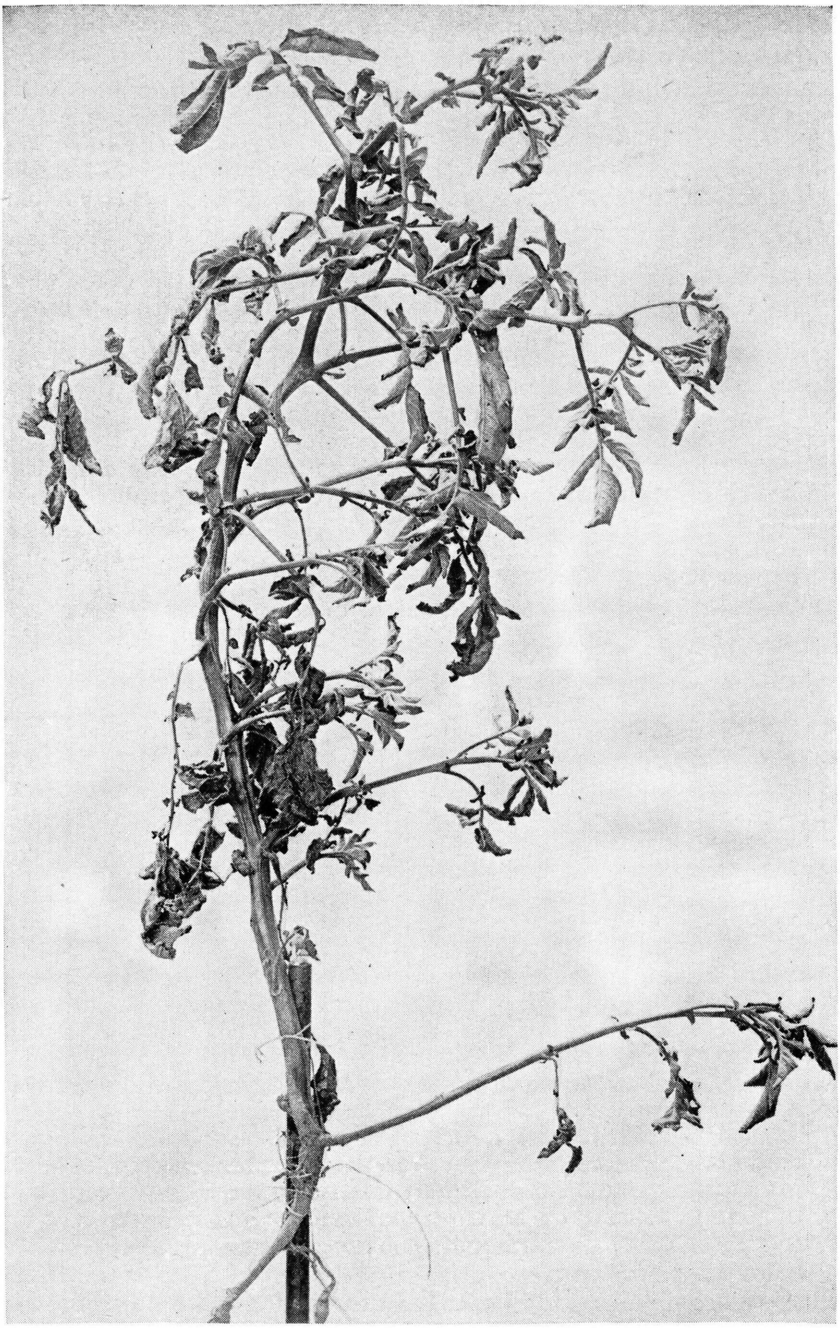

FIGURE 15.—Potato plant showing wilt caused by *Fusarium oxysporum*.

lower, older leaves. Other symptoms are similar to those described previously. Yellowing and drying of the leaves proceed from the base upward until there is often only a cluster of green leaves at the top.

On hot days yellowing is preceded by wilting of the leaves and even of the stalk.

The stems of affected plants are always discolored in the interior. The interior woody tissues of the stem are yellow to brown, often from the base well into the top. In some cases the young top leaves wilt and die before the lower ones. They look as if scalded. If these symptoms are those of wilt, the fact may be determined by cutting away the bark at the base of the stalk. The disease is likely to be wilt if the woody tissue beneath the bark is brown, for healthy tissue has a white or a faint yellow color. The brown color may extend all the way around the stem or may be confined to one side. All the fine feeding roots and the bark of the larger taproot become entirely decayed. Tubers from affected plants may show a brown or black discoloration of the vessels. This, however, is not a certain symptom of wilt, since discoloration of the vascular ring of the tubers and stems, indistinguishable from that caused by the wilt fungi, may be brought about by other conditions.

If the wilt is caused by *Fusarium eumartii*, the symptoms differ slightly from those described in the preceding paragraphs. On the foliage the first indications of the disease are small, light-green areas between the veins of the leaflets, giving them a mottled appearance; these areas gradually turn yellow. The yellowing is often accompanied by a bronzing of the upper surface of the leaf in smaller irregular spots. If the soil moisture is high, the foliage symptoms may never advance to the wilting stage. Under such conditions the leaves may show yellowing, rolling, and rosetting, sometimes accompanied by the development of aerial tubers and other symptoms which follow injury to the stem. In case of a slight attack the plants may never show symptoms more severe than the faint mottling. With a medium soil moisture and a heavy infection the mottling becomes extended until the whole leaf surface is involved and the leaf turns yellow, dries, and droops, often hanging to the stem by a thread. Sometimes an internal blackening of the small veinlets, the veins, and the petioles is observable at the surface.

When infection takes place through the roots, the root hairs and fine roots are often completely destroyed. Under dry conditions the cortex of the affected roots is brittle and breaks off easily. In this type of infection the disease works up and down the stem from the point of infection. The browning is most conspicuous in the vascular region but gradually extends through the pith cells, appearing as a light-brown discoloration or flecking. The discoloration is more marked at the nodes.

Recommendations for Control

The fungi causing wilts are able to pass the winter in affected tubers and the soil. It is not known how long they can persist in the soil, but severe attacks have occurred in soils in which potatoes had not been grown previously. Only wilt-free seed potatoes should be used.

DRY ROTS

Dry rots, caused by *Fusarium coeruleum* (Lib.) Sacc. and *F. trichothecioides* Wr., are generally referred to as storage dry rots; some form is likely to occur wherever potatoes are stored. The one caused by *F. coeruleum* seems to be the commonest; generally this fungus

enters the potato through wounds and produces large sunken pockets or a wrinkled decay. Numerous bluish or whitish points, or protuberances, are formed on the surface of the decayed parts (fig. 16).

The rot caused by *Fusarium trichothecioides* is known as powdery dry rot and is limited chiefly to sections having warm, dry summers. It is prevailingly western in distribution. Affected tubers shrink con-

FIGURE 16.—Potato tuber sliced lengthwise to show dry rot caused by *Fusarium coeruleum*.

siderably, and in the interior they often develop large, hollow pockets partly filled with a brick-colored powdery mass of fungus growth. Pinkish or whitish tufts of fungus growth are occasionally produced freely on the surface of the sunken rotted areas.

Many virgin and cultivated soils are infested with these organisms; the species predominating depends on the conditions. Potatoes that are bruised or otherwise injured and kept under humid conditions become readily infected.

Recommendations for Control

Prevention of dry rots consists essentially in careful handling to reduce mechanical injury to the minimum. Control consists in storing the tubers in air sufficiently humid to promote suberization and after that in keeping them dry. At a temperature of 41° to 55° F. rot progresses very slowly.

Early blight, caused by *Alternaria solani* (Ell. and G. Martin) Sor. and also known as leaf spot, occurs earlier in the season than late blight; however, it is also rather common late in the season if weather conditions are favorable for its development. It attacks the potato stems and leaves, causing brown spots which develop concentric rings or markings as they enlarge and produce a target-board pattern (fig. 17). When the spots are numerous they kill the leaves and consequently reduce the yield of potatoes.

FIGURE 17.—Potato leaf showing early blight lesions.

Sometimes the early blight fungus causes small, shallow, more or less circular decayed lesions on the tubers. The margin of the diseased area is raised somewhat, and the immediately adjoining skin is slightly puckered. The lesion may afford an entrance for saprophytic molds that complete the rotting of the tuber. This is especially true if seed potatoes are shipped to Florida or other southern points where the high temperature is favorable for the growth of decay organisms.

Recommendations for Control

Early blight can be successfully controlled by early and thorough spraying with bordeaux mixture. In preliminary trials Dithane, a new organic fungicide, when combined with zinc sulfate and lime gave excellent control.

LATE BLIGHT

Late blight, caused by *Phytophthora infestans* (Mont.) DBy., is one of the most destructive diseases in New England and the North Central States. Ordinarily it is not of great importance in the Southern, the Middle Western, or the Pacific Coast States, but during some years when climatic conditions are favorable for the development of the disease it may also occur in epidemic form in these sections.

The disease is known as late blight because in most sections of the country it attacks plants at the blossoming stage or afterward. In some places, however, including the Pacific coast section and the northern Atlantic seaboard, the disease in some seasons may appear and kill the plants as early as June. Late blight appears on the leaves as pale-green, irregular spots. In moist weather these increase rapidly in size, the centers of the spots die and turn brown or black, and on the lower sides of the leaves a white mildew ring forms around the dead areas. The stems may be affected, and under humid conditions the entire vine may be killed and blackened in a short time. Under favorable, warm, moist weather the disease spreads rapidly and all the plants in a field may be killed in a few days. The diseased and decaying plants give off a characteristic odor, which becomes very pronounced in fields that are severely attacked.

Tubers are readily attacked while in the soil by rain-borne spores from blighted tops and at harvest by contact with blighted foliage. Late blight that develops on tubers in the soil is primarily brown and spreads irregularly from the surface through the flesh like the diffusion of a brown stain. At first the affected tissue is dry and firm, but soft rots that destroy the tuber often follow the late blight rot. Some blighted tubers rot in the field, especially in low, wet spots. In storage the disease is typically a dry rot, forming irregular, sunken patches, which, under conditions favorable for their development such as high humidity and temperature, may involve the entire tuber. At low storage temperatures the patches usually remain rather firm; frequently they have a metallic tinge, especially at the border of healthy tissues.

It has been known for a long time that late blight fungus may grow from a diseased seed tuber up the stem to the surface of the soil, sporulate, and thereby cause infection of the foliage. That the

planting of late-blight-infected tubers, however, does not always result in infected plants was shown in experiments conducted in Maine; these demonstrated that a very low percentage of infected tubers developed infected shoots. The probable reason is that under normal field conditions the diseased shoots often die before they emerge from the soil. This is especially true if they are planted deep. Although the number of seed tubers that develop infected shoots is very small, they may still be a serious source of infection. Sometimes infected sprouts may emerge through the soil and die 1 or 2 days later, leaving only a small black tuft of decaying tissue. As it is difficult to locate such tissue, the vacant spot is apt to be attributed to a missing hill. During the period that the infected sprout is above ground, the spores produced on it have an opportunity to spread to one or more adjoining plants and to produce an infection spot in the field. Under favorable conditions the fungus can spread readily from this spot to other plants in the field.

Observations in Maine and other States have demonstrated that cull piles of potatoes outside of potato storage houses, along railway tracks, and on farms are a primary source of infection. These cull piles often contain a high percentage of late-blight-infected tubers. The young shoots from such tubers are infected with late blight. Such infections generally develop during the early part of the growing season before most growers have begun to spray. The spores may be carried by the prevailing winds to the neighboring fields and infect the young potato plants (fig. 18). Early infections spread rapidly when the weather conditions, such as drifting mist and fog and wind-blown rains, are favorable. Late blight, when first observed in the field, often appears as small isolated spots on the top leaves or stems of the potato plants, indicating that spores have been brought in from a distance. The disease may appear in this way at about the same time in a number of fields distributed over a large area, indicating wind dissemination.

FIGURE 18.—Potato field heavily infected with late blight as a result of spread of the disease from a nearby infected cull pile. (By courtesy of the Maine Agricultural Experiment Station.)

Since cull piles constitute one of the chief early sources of late blight infection, their elimination will do much to prevent the spread of late blight. These potato dumps should be treated with a herbicide to destroy the potato sprouts or with bordeaux mixture or a copper sulfate solution to control infection. In view of the difficulty of destroying potato tops on dumps, however, it would be much better not to dump waste potatoes. Disposing of them by boiling, burning, or feeding to livestock will prevent development of infected plants and the subsequent job of spraying or destroying such tops.

Spraying for the control of late blight should begin when the plants are about 4 inches high and before the disease develops. The foliage should be thoroughly covered with a layer of bordeaux mixture. Detailed instructions for preparing and applying sprays are given on page 6 and for dusts on page 7.

If partly blighted vines are present when the tubers are dug, especially during moist weather, considerable tuber rot may develop. In running the digger over the vines, late blight spores are scattered to tubers. Many farmers fail to detect small amounts of the disease on the partially dead stalks and leaves, or they consider that such small amounts will cause no loss. If the freshly dug tubers, however, are picked up moist and taken immediately to storage or pits without drying, the conditions are ideal for the development of a high percentage of tuber rot. It has been observed that little or no rot occurs when the potato plants are completely killed by late blight early in the season, because at digging time all the spores are dead.

To avoid tuber rot it is best to delay digging until the potato tops have been dead at least 2 weeks, preferably until after a killing frost. Otherwise it is advisable to kill the blighted tops with a herbicide 10 days before harvest to prevent blight infection of tubers at harvest. It may sometimes be necessary to spray the old vines and the entire soil surface with a solution of copper sulfate at the rate of 10 pounds to 50 gallons of water, especially when infection occurs late in the season and the spores are still viable at digging time.

Although most common varieties of potato are very susceptible to late blight, Sebago, one of the new late varieties developed by the United States Department of Agriculture, is moderately resistant and during years of moderate blight epidemics will produce a good crop without any spraying. Better results are obtained if even this variety is sprayed during such years, but the applications of spray may be less frequent than on susceptible varieties. Other varieties which are even more resistant than the Sebago are being developed by the United States Department of Agriculture in cooperation with the State agricultural experiment stations, but they are not yet ready for distribution.

SILVER SCURF

Silver scurf, caused by *Spondylocladium atrovirens* Harz, appears to be generally distributed over the United States. The affected parts of the potato skin often are smudgy or sooty when the tubers are left undisturbed in storage, or they may take on a silvery appearance that is seen best when the tubers are wet. These spots may be large or small, but generally they are ¼ to 1 inch in diameter and most abun-

dant on the stem-end half of the tuber. The disease causes some loss in potatoes in storage by injuring the skin and permitting considerable loss of water and consequent shriveling. Although the table value of the potatoes is not impaired in mild cases, badly affected and shriveled tubers may become practically unsalable.

Recommendations for Control

The development of silver scurf in storage can be checked by keeping the tubers at low temperature and humidity. Although the disease cannot be entirely controlled, it is considerably reduced by seed treatment with mercuric chloride (p. 2). Seriously affected tubers should not be planted, and long rotations should be followed.

ROOT KNOT AND OTHER NEMATODE DISEASES [3]

Root knot (nematode gall), caused by nematodes, or eelworms (*Heterodera marioni* (Cornu) Goodey), has become a serious factor in potato culture in many potato-growing regions throughout continental United States not only because of the direct injury to the potato crop but also because planting infected potatoes is one of the most effective means of spreading the disease to the many other crops that are subject to it. The parasite invades the roots and tubers in many different places and produces lesions, swellings, or galls, varying in shape and size. The individual galls are more or less round, but they frequently run together and then the tuber takes on a knotty and irregular appearance. When cut, such potatoes show a line of tiny, glistening spots (the female nematodes) and slightly discolored spongy (watery) areas just beneath the swelling. The root knot nematode attacks a large number of commonly cultivated plants and causes immense damage in some instances. Feeding roots when seriously attacked by the nematodes are unable to function properly and the growth of the plant is checked.

Another species, Scribner's meadow nematode (*Pratylenchus scribneri* Steiner), also attacks potatoes. The tuber appears spotted in certain areas or is covered over its whole surface by slightly elevated pustules. Sometimes these pustules run together. After the potatoes have been dug and have shrunken somewhat, the diseased areas of a tuber may become surrounded by shallow channels as a result of the collapse of the immediately adjacent tissues; this shrinkage may be sufficient to cause the whole of a diseased area to appear as a depression.

Both of these species of nematodes are able to spread in the soil very slowly to noninfested areas. They can be easily carried from field to field, however, by running water or by soil clinging to agricultural implements, the hoofs of animals, and the feet of men.

Two other nematode pests of potatoes have been found in this country, but so far as known they are restricted in their occurrence. These are the golden nematode of potatoes (*Heterodera rostochiensis* Wr.), limited to a district on Long Island, N. Y., and the potato rot nematode (*Ditylenchus destructor* Thorne), limited to a district in Idaho.

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[3] Revised by Division of Nematology, Bureau of Plant Industry, Soils, and Agricultural Engineering.

Recommendations for Control

Where root knot nematodes have become established in the soil they can be starved out by a 3-year rotation with nonsusceptible crops provided weeds and volunteer plants of susceptible crops are rigidly excluded. As an aid in accomplishing this, it is well to have at least some of the rotation crops planted in rows and thoroughly cultivated to insure complete absence of weed hosts. Clean fallow is most effective because parasitic nematodes cannot exist long without living hosts. Most of the nematodes die during the first and second years of clean fallow. Special care should be used to insure that the pests are not introduced into the field in seed potatoes. No potatoes from a field known to be infested should ever be used for seed; a mere inspection of the tubers will not reveal light infection, and the introduction of the disease into the field might very easily be accomplished in this way. Detailed descriptions and recommendations for control are given in Farmers' Bulletin 1345, Root-Knot: Its Cause and Control.[4]

Recent experiments have shown that infested fields can be rendered productive by the use of soil fumigants, such as ethylene dibromide, dichloropropene, or mixtures containing them. Soil fumigation with these chemicals is considered profitable where the value of the land justifies the expense of application. Detailed instructions for the application of the various fumigants are furnished by the manufacturers.

TIPBURN AND HOPPERBURN

Tipburn and hopperburn may be regarded as two distinct diseases. The symptoms, however, are very similar and consist of a gradual dying and blackening of the tip and margins of the leaflet, preceded by a slight yellowing of these parts. More than half of the leaf surface may die. These affected margins roll upward, and all the dead tissue becomes very brittle so that it frequently is broken or torn. Plants affected with virus diseases such as leaf roll or spindle tuber are more susceptible than healthy plants.

Tipburn is caused by excessive loss of moisture from the leaves during hot, dry weather. The withdrawal of water from the tissues may eventually cause the death of the leaves if the condition is not relieved by rainfall or by a reduction in temperature.

The potato leafhopper (*Empoasca fabae* (Harr.)) has been shown to be a more usual cause of tip burning, but the effect is then known as hopperburn. This insect sucks the plant juice from the midrib or other veins, but the browning of the leaves results apparently from a toxic substance transmitted by the leafhopper. The development of symptoms is not dependent upon temperature and moisture conditions, but the severity of the symptoms is increased by high temperature and lack of moisture.

Recommendations for Control

Cultural practices that conserve soil moisture are helpful in reducing tipburn, and frequent applications of bordeaux mixture will help to control both tipburn and hopperburn. Pyrethrum powder alone or mixed with sulfur is effective against the potato leafhopper.

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[4] Out of print; may be consulted in libraries.

As stated previously, there are three species of flea beetles that attack the potato: namely, the potato flea beetle (*Epitrix cucumeris*), the western potato flea beetle (*E. subcrinita*), and the tuber flea beetle (*E. tuberis*). The first is probably the most important of the three species for the country as a whole. The damage caused by the feeding of the adult beetles on the foliage is considerable, but the loss caused by the feeding of the larvae on the tubers is unquestionably of more importance. The larvae live in the soil and feed on the roots and developing tubers. The feeding of larvae on or near the surface of the tubers causes roughened pustulelike scars; deeper feeding causes

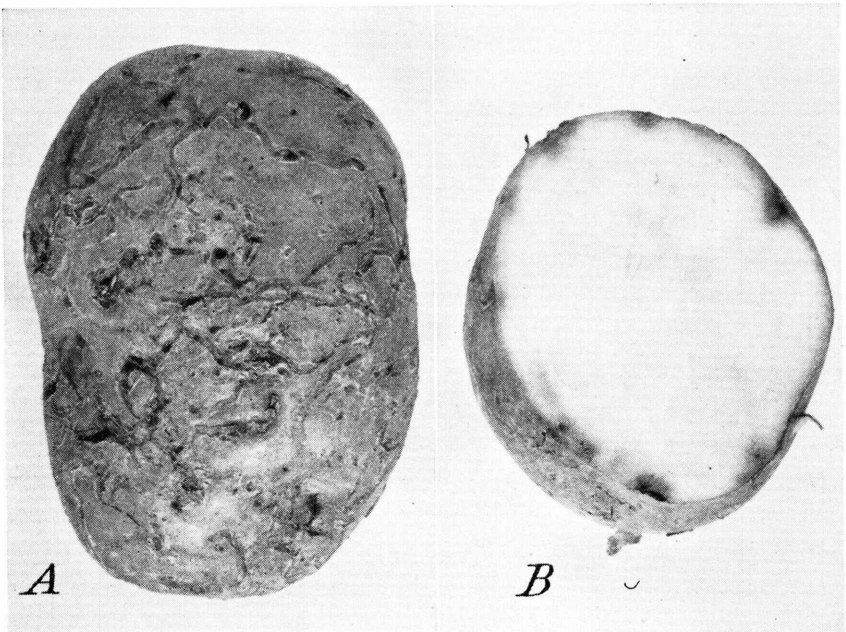

FIGURE 19.—*A*, Potato tuber showing tracks caused by larvae of flea beetles; scab infection takes place readily in such tubers. *B*, Tuber showing injury caused by the larvae inside of the potato.

the formation of corky slivers about one-fourth inch long that extend into the potato at right angles to the surface. Tuber injury is further increased by common scab infection in the wounds made by the larvae, which causes the scars to increase in size and depth (fig. 19).

Recommendations for Control

Spray experiments conducted in Virginia against *Epitrix cucumeris* showed that the most effective control was obtained by spraying the plants with 4–6–50 bordeaux mixture to which 2 pounds of calcium arsenate had been added. The best results were obtained with this material when it was applied six times at 7- to 10-day intervals throughout the growing season. Late spraying seemed to be more

important than early spraying because the new brood of flea beetles, which appears about June 20 on the Eastern Shore of Virginia, is more abundant and injurious than the overwintering brood found in the field earlier in the season. As the potato flea beetles feed on both surfaces of the leaves, care should be taken that the nozzles of the sprayer are adjusted so that the undersurface of the leaves will be thoroughly covered with the material used. (See also p. 43.)

Spray experiments in the State of Washington also demonstrated that calcium arsenate added to bordeaux mixture was the most effective of the combination treatments, but complete control of tuber injury was never obtained. Flea beetles may be controlled by insecticide dusts containing 45 percent of cryolite (approximately 40 percent of sodium fluoaluminate) and 55 percent of talc or 25 to 40 percent of calcium arsenate and 60 to 75 percent of talc. DDT sprays and dusts are also effective. (**See warning,** p. 6.)

It was definitely demonstrated in the State of Washington that the dates on which potatoes are planted have a direct bearing on the severity of the flea beetle injury to tubers. This relation is largely due to the life history of the insect, as there are only one complete generation and a partial second generation annually. In order to escape invasion of the new tubers by the larvae, it is recommended that early potatoes be planted during March if possible and not later than April 19. Late potatoes should be planted between June 15 and July 15. Potatoes planted during this period developed tubers relatively free from tuber damage without the use of any insecticide. In districts where potato flea beetles are troublesome no potatoes should be planted between April 19 and June 1. Similar results were obtained in Oregon.

VIRUS AND VIRUSLIKE DISEASES

Viruses are carried over in seed potatoes, and growers of certified seed make every effort to eliminate from their seed stocks plants infected with such diseases. Growers of table stock should therefore use certified seed known to contain at most only a small percentage of tubers affected with virus diseases. Aside from obtaining the best seed, ordinarily they cannot apply any control measures. With few exceptions the viruses do not affect the eating quality of potatoes, but they do reduce the size and the number of tubers produced per plant. Current-season symptoms of leaf roll are one of the exceptions.

Brief descriptions of various virus diseases are given so that growers of table stock can recognize them and not apply control measures that will not benefit them.

MILD MOSAIC

Mild mosaic can be recognized by a mottling in the green of the leaf, in which yellowish or light-colored areas alternate with the normal green. The mottling is accompanied by a slight crinkling. These mottled areas are variable in size and are not limited by the veins (fig. 20). Diseased plants droop and die prematurely.

Mosaic mottling is modified by climatic conditions. In the northern seed-growing sections it is usually more distinct during the early part of the season. When certain seasonal conditions, usually hot and more or less dry weather, continue during the entire growing season,

mosaic mottling is very difficult to detect. Although under such unfavorable conditions mottling may not be apparent, it does not follow that such plants are free from the disease. These plants or their progeny will show the mottled symptoms if placed under conditions favorable for their development.

The United States Department of Agriculture has developed and recently introduced a number of varieties, namely Katahdin, Chippewa, Houma, Sebago, and Earlaine, that do not contract the disease in the field. These varieties are not immune, however, since the virus can be transmitted to them experimentally by grafting; but for practical purposes they are as valuable as if they were immune.

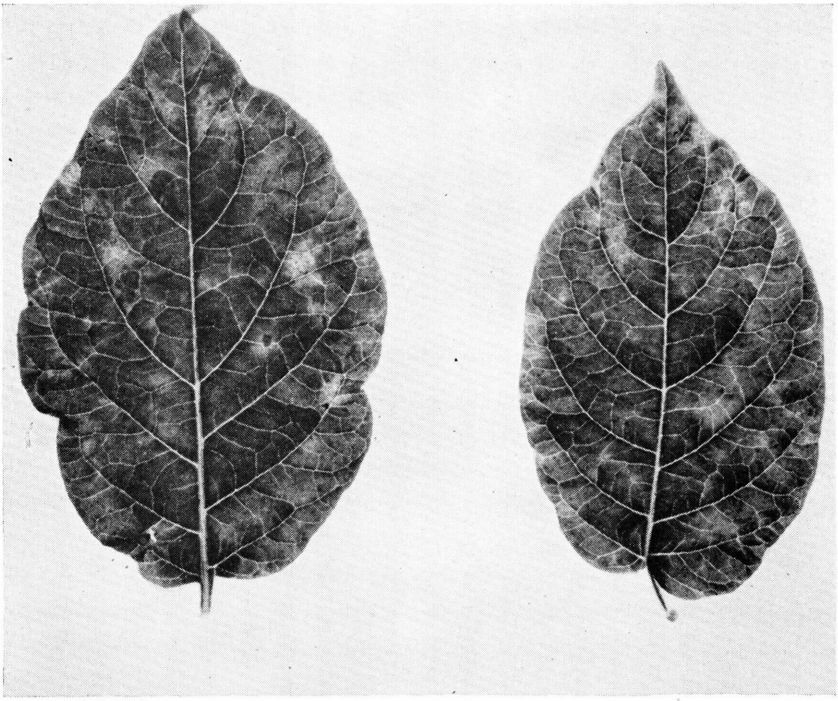

FIGURE 20.—Leaflets from a Green Mountain potato plant affected with mild mosaic. Note the yellow patches ihterspersed in the normal green.

RUGOSE MOSAIC

Rugose mosaic, a more serious disease than mild mosaic, is entirely distinct from it. The mottled areas are smaller and more numerous, and typically they are distributed closer to the main veins. The mottling is readily masked under high-temperature conditions, but the crinkling and rugosity of the leaves make identification rather certain. The veins on the under side of the lower leaves often show necrotic areas as black pencillike lines. Affected plants are considerably stunted and die much earlier than healthy ones.

Rugose mosaic is spread by aphids to other plants in the field. If infection takes place early in the season, current-season symptoms are

apt to develop before the plant dies. If infection occurs late, symptoms may not appear the same season, but tubers from such plants will carry the disease. Current-season symptoms are characterized by a burning and discoloration of the leaf veins and blades, brittleness, leaf dropping, and premature death. At first these symptoms may appear only on a single shoot in a hill; late in the season other shoots in the same hill may show these symptoms (fig. 21).

FIGURE 21.—Potato plant showing current-season symptoms of rugose mosaic.

LEAF ROLL

Leaf roll is characterized by the upward rolling of the leaflets lengthwise so that the midrib remains at the middle of the trough thus formed. The plants infected when young show rolling first of the lower leaves and then of progressively higher ones until all leaves may be rolled (fig. 22). Other symptoms include dwarfing, rigidity, leathery texture, chlorosis, reddish or purplish discoloration of the affected leaves, and reduction in the number and size of the tubers. If plants become infected during the current season, they may show rolling only in the upper leaves. If infection takes place early enough, eventually all the leaves will show rolling.

In certain varieties another symptom of current-season infection is net necrosis of the tubers. This consists of small brown strands of discolored tissue extending throughout the interior tissue of the potato tuber at the stem end (fig. 23). This condition so affects the grade of table stock that, if net necrosis in excess of a designated percentage occurs in a lot of potatoes, they cannot be sold as U. S. No. 1. The

Green Mountain and Irish Cobbler varieties develop net necrosis readily, whereas some of the newer varieties such as Katahdin, Sebago, and Chippewa remain practically free from it even with an appreciable increase in leaf roll spread.

Recommendations for Control

In localities where leaf roll spreads rapidly and varieties susceptible to net necrosis are grown, it may be advisable to rogue infected plants to avoid an excessive amount of net necrosis in tubers.

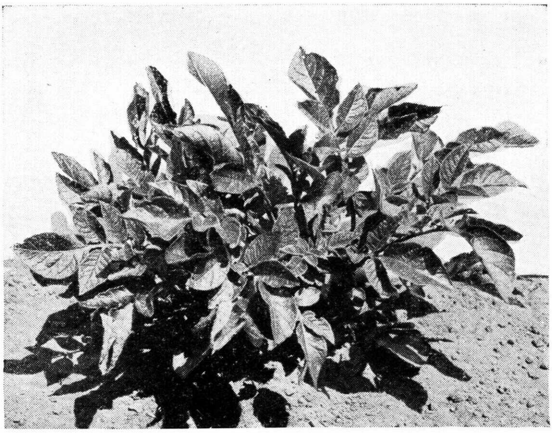

FIGURE 22.—Burbank potato plant affected with leaf roll. Rolling is particularly prominent in the lower leaves, but it is evident also in the upper ones. The foliage tends to be rigid, not soft and flexible as in normal plants. Diseased plants are noticeably stunted and lighter than the healthy ones.

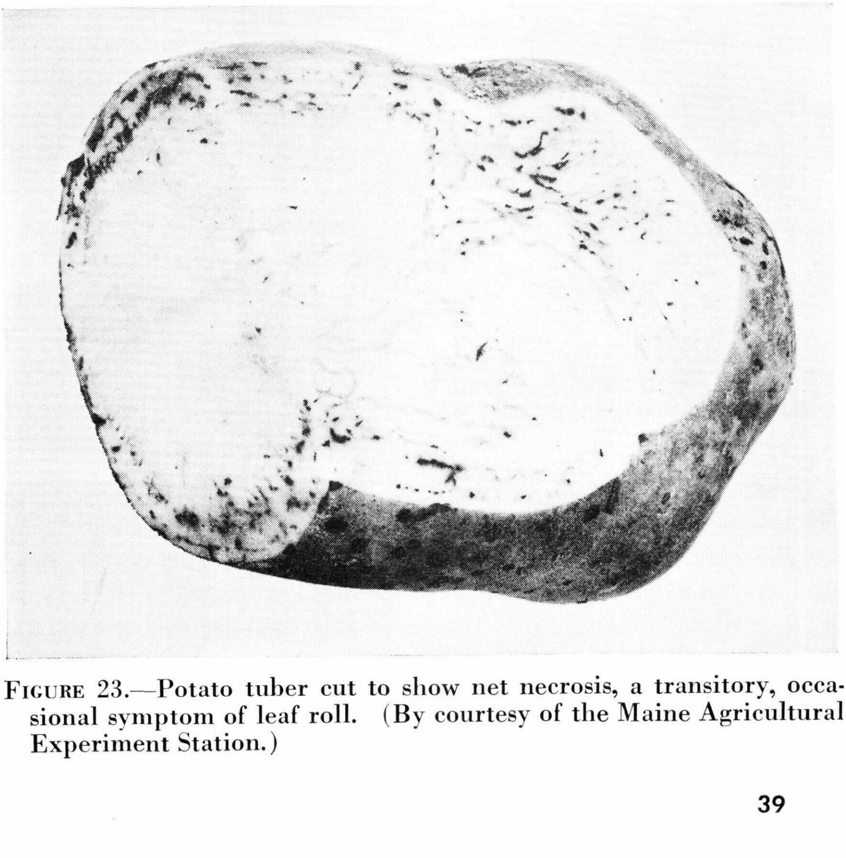

FIGURE 23.—Potato tuber cut to show net necrosis, a transitory, occasional symptom of leaf roll. (By courtesy of the Maine Agricultural Experiment Station.)

SPINDLE TUBER

Spindle tuber is so named from the spindle-shaped tubers produced by diseased plants. Affected plants are characterized by slenderness and uprightness, and the foliage is darker green than that of healthy plants. Diseased Triumph tubers are lighter red than the healthy ones and have a tendency to be longer. Long tubers become especially spindling and pointed at the stem end (fig. 24). Shallowness of eyes and increase in their number are characteristic of this disease.

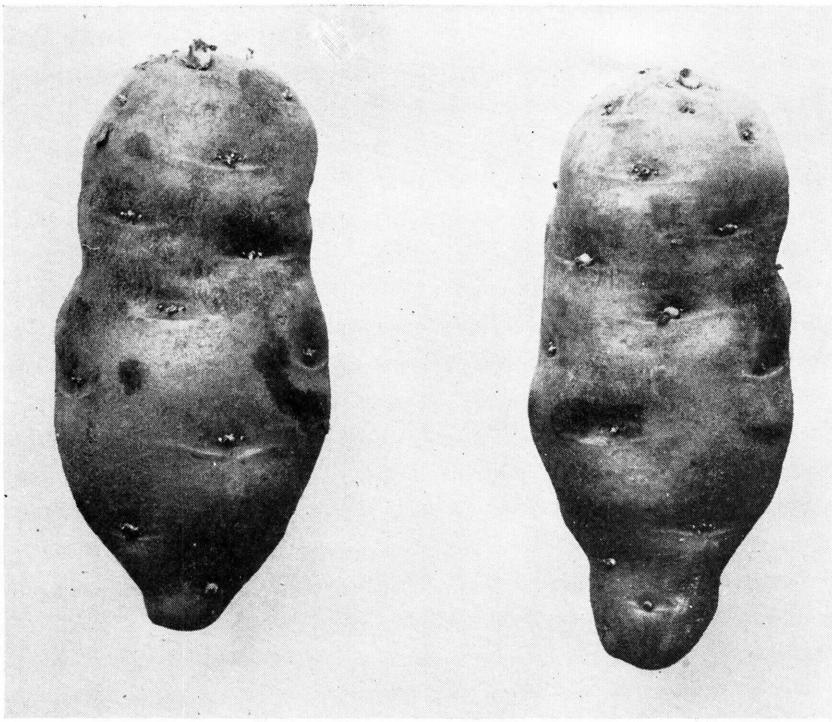

FIGURE 24.—Green Mountain potato tubers affected with spindle tuber. Note that such tubers are elongated and more pointed at the stem end than normal ones.

WITCHES'-BROOM

Witches'-broom seems to occur primarily in some of the Northwestern States. Affected plants produce numerous slender, spindling sprouts of which none succeeds in producing a large plant or any appreciable yield. The leaves may be very small and somewhat velvety. Infected plants may not grow taller than 9 inches, and they produce a large number of potatoes no larger than marbles. When affected tubers germinate they often produce numerous spindling sprouts.

The way in which this disease spreads from plant to plant is not known. As it shows up in stock formerly healthy, it presumably is

spread by some insect; however, all experimental work carried on to determine the identity of the insect has given negative results.

YELLOW DWARF

Yellow dwarf has been reported from some of the Eastern and Midwestern States, but as yet it has not been found in the Pacific Northwest. The foliage of affected plants takes on a yellowish-green color, and the upper surface of the leaves becomes slightly rugose (fig. 25). Dying from the tip downward is characteristic, but under some conditions this symptom may be absent. High temperature and low humidity tend to hasten the death of infected plants. In the pith of the stem brown spots are common. They appear shortly after yellowing of the foliage and may eventually extend the entire length of the main stem. In warm soil seed pieces from infected tubers often fail to germinate; other seed pieces produce shoots that die before they reach the surface.

The effect of yellow dwarf on the tubers varies. Infected plants often produce small, misshapen tubers, which in cross section show

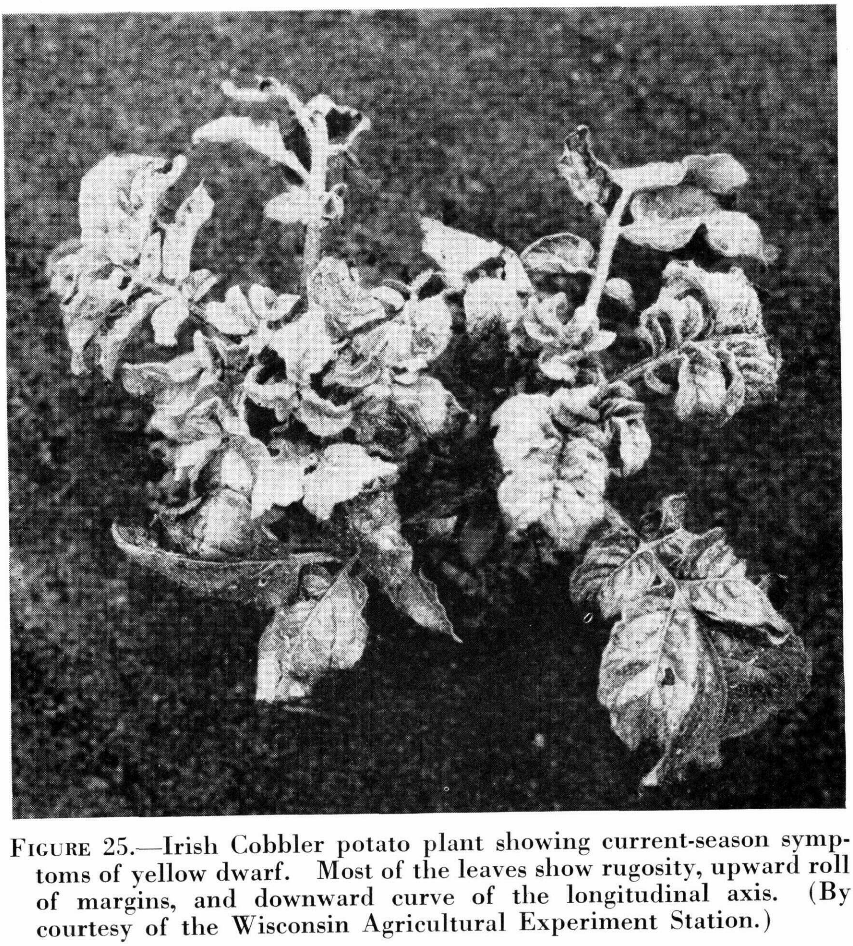

FIGURE 25.—Irish Cobbler potato plant showing current-season symptoms of yellow dwarf. Most of the leaves show rugosity, upward roll of margins, and downward curve of the longitudinal axis. (By courtesy of the Wisconsin Agricultural Experiment Station.)

small necrotic areas scattered throughout the flesh. Growth cracks are common, but these are also characteristic of certain other diseases.

HAYWIRE

Haywire has been found in a number of the Mountain States; although the disease is generally not important, the affected plants are very noticeable. This disease is believed to be of virus origin because apparently it has been transmitted to healthy potato plants by the inarch method of grafting. According to reports such abnormal plants have been observed for at least 15 years, but until the last 8 or 10 years they have not occurred in numbers large enough to cause any great concern. The disease is characterized by late emergence or missing hills, and sometimes the dormant seed pieces produce sprout tubers. The plants are severely dwarfed and have a rosette appearance due to a cessation of the terminal growth, a shortening of the internodes, and an increase in the number and development of axillary shoots. The leaflets are usually rugose, erect, stiff, rolled, pointed, and slightly yellowish; often they have a purple coloration at the tips and margins. Petioles and stems may show swellings at the nodes with a red or purple pigmentation. Sometimes aerial tubers are formed in the leaf axils. Tubers are few and set close to the stem or are lacking.

CALICO

Calico is a disease characterized by the occurrence of large, irregular yellow to cream-colored spots on the leaves. In some cases as much as 70 percent of the leaf surface may entirely lack chlorophyll; again only occasional leaves may show a few spots. Generally, however, the spots are numerous and well-distributed over the plant. The disease appears to be systemic, as generally all the tubers from an infected hill will give rise to the same condition if used for seed.

PSYLLID YELLOWS

Psyllid yellows is induced by some toxic substance injected into the plant during the feeding of the nymph of an insect known as the potato, or tomato, psyllid (*Paratrioza cockerelli* (Sulc)). Although not caused by a virus, this disease is systemic in nature and results in a complete upsetting of the form and physiology of the entire plant. It is known to occur in the Western States and is especially serious in some parts of Colorado, Utah, and New Mexico. During certain years it causes severe damage in Nebraska, Wyoming, and Montana.

The first symptoms consist of a marginal yellowing and an upward rolling of the basal part of the smaller leaflets on the young leaves of affected plants. Under field conditions, especially when diseased plants are exposed to intense sunlight, the basal rolling or cupping of the young leaves in all varieties observed becomes very pronounced. The rolled portions and frequently other parts of the leaf assume a distinctly reddish or purplish color. The older leaves of the diseased plant roll upward over the midrib and become yellow. Brown necrotic areas develop and bring about the early death of the entire leaf. Buds above and below the ground are stimulated into activity. Above ground the axillary buds may develop into

stocky shoots that frequently branch; when fully developed, they give the plant a compact and pyramidal shape. In some cases the axillary buds develop into aerial tubers along the entire stem or produce short leafy shoots with rosettes of small leaves which in advanced stages of the disease may become bright yellow. Several tubers may develop along a single stolon and numerous small potatoes result (fig. 26). Of all the diseases of the potato, psyllid yellows is the most disastrous; it often results in complete crop failure. If the plants are attacked when young, no crop is produced.

Recommendations for Control

Spraying potato plants with lime-sulfur-zinc-arsenite has given excellent results in controlling psyllids as well as flea beetles (p. 35). The formula consists of 1¼ gallons of liquid lime-sulfur (32° Baumé), 2½ pounds of zinc arsenite, and 50 gallons of water. The solution is applied at 350 pounds' pressure with three nozzles to the row. It is advisable to stagger the lower nozzles to get a tipping and swirling action, which gives better coverage of the lower leaves. Growers are advised to make two or more applications of the spray mixture. The first application is made when the plants are 6 to 8 inches high; the others follow at intervals of 10 days to 2 weeks. **(See warning,** p. 6.)

The disease is not carried over in the tuber, but plants grown from infected tubers are generally weakened.

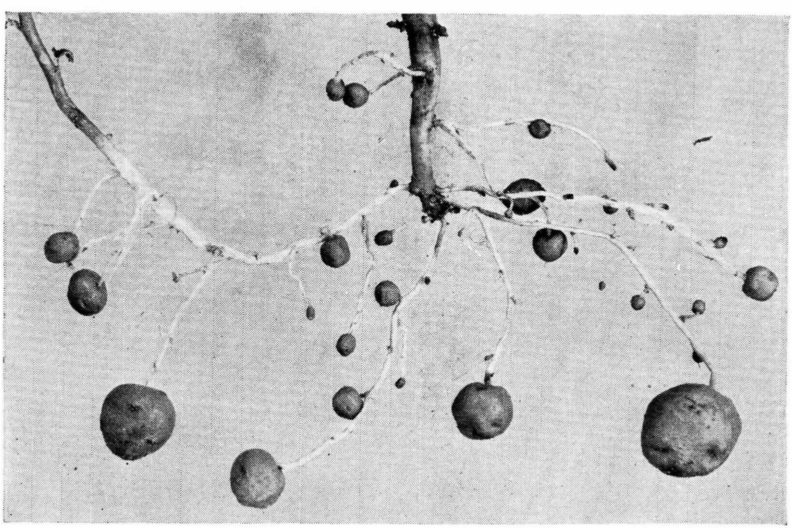

FIGURE 26.—Underground part of a Triumph potato plant affected with psyllid yellows. Note that one stolon had developed directly into a new shoot and that others had given rise to secondary stolons or tubers at their nodes. A diseased plant of this type may produce 50 to 150 tubers; at the time this plant was dug, it had 46 tubers already set.

Purple-top wilt, which in the more advanced stage has symptoms that resemble those of psyllid yellows, is most abundant in the northern and eastern parts of the United States. It has been reported from New York State westward to Minnesota and North Dakota and southward through the mountainous sections of Pennsylvania and West Virginia. It has not yet been reported from any State in the South or the far West.

The first symptoms of purple-top wilt appear at the apex of the plant. The young leaves fail to enlarge normally, and the leaflets roll upward. The most pronounced rolling is at the base of the leaflet. In varieties with red pigment the coloration is accentuated, the purple

FIGURE 27.—Shoots of the Chippewa variety of potato showing symptoms of purple-top wilt. Some of the leaves were removed to show swollen stems of the axillary shoots. (By courtesy of the West Virginia Agricultural Experiment Station.)

color being most intense at the base of the leaflet, where the curling is most evident. Pigmentation is usually accentuated also on the stems of diseased plants, being especially pronounced in the Rural New Yorker No. 2 variety.

In varieties lacking pigment the topmost leaves become chlorotic and assume a light-green or yellow cast when they are affected with purple-top wilt. An abnormal number of axillary shoots develop and soon show the symptoms just mentioned. The axillary shoots become swollen at the base and often form distinct aerial tubers (fig. 27). The vascular tissue of the stem turns brown at the time the foliage symptoms appear. The brown bundles may extend only a few inches above ground, but usually they extend well into the stolons. Necrotic flecks are often present in the pith of the lower part of the stem. An affected plant generally wilts within 2 weeks after the symptoms appear, and death may soon occur. Plants affected in late summer may mature late, and when these are killed by frost the stems turn intensely black. An internal necrosis of tubers extending from the stem end is characteristic of the disease on Rural New Yorker No. 2 in West Virginia but may be absent on this and other varieties in other sections. Occasionally tubers from infected plants are flabby.

According to experiments conducted in Minnesota purple-top wilt is due to the virus that causes aster yellows; that virus is carried by the six-spotted leafhopper (*Macrosteles divisus* (Uhl.)). Purple-top wilt is not transmitted as such through the tubers, but the tuber progeny of plants affected with the disease is much less vigorous than that of healthy plants.

Recommendations for Control

No control for purple-top wilt is known.

DISEASES DUE TO NONPARASITIC CAUSES

Diseases described as due to nonparasitic causes are not known to be caused by any virus, fungus, insect, or bacterium; they seem to be due to unfavorable environmental conditions.

INTERNAL BROWN SPOT

Internal brown spot is characterized by irregular, dry, brown spots or blotches scattered through the flesh of the tuber. Such spots are not restricted to the water vessels (fig. 28) as is the case with vascular diseases. They consist of groups of dead cells free from bacteria and fungi. No definite foliage trouble is associated with internal brown spot.

Recent experiments in Germany have demonstrated that there is a close relation between this trouble and the lack of available soil moisture late in the growing season; lack of water is more injurious to some varieties than to others.

Recommendations for Control

No measures that will prevent the occurrence of internal brown spot in the field have been worked out. Favorable cultural conditions may, however, reduce its severity.

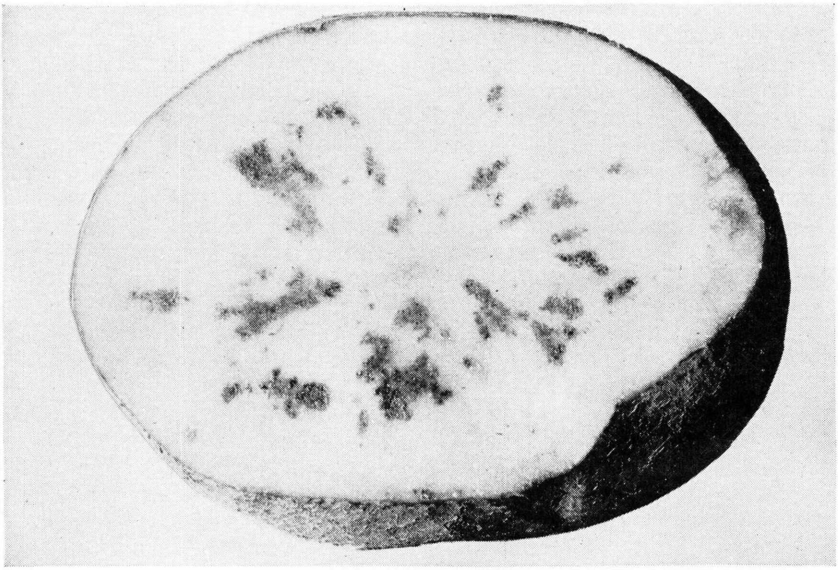

Figure 28.—Section of a potato tuber showing internal brown spot.

STEM-END BROWNING

The cause of stem-end browning has not yet been fully determined, but from present knowledge it is attributed to nutritional disturbances. There is no evidence that the trouble is transmissible. In other words, the planting of tubers affected with stem-end browning is not reflected in reduced yields in comparison with those from clear-flesh tubers. Seasonal conditions, cultural factors, use of certain kinds of fertilizers, chiefly those containing a large content of chlorine, and storage temperatures, the last-named in particular, have been found to have some effects on its prevalence. Stem-end browning may sometimes be confused with net necrosis (p. 38). The brown discoloration associated with stem-end browning, however, does not as a rule penetrate the tuber more than half an inch, whereas that of net necrosis is usually deeper (fig. 29).

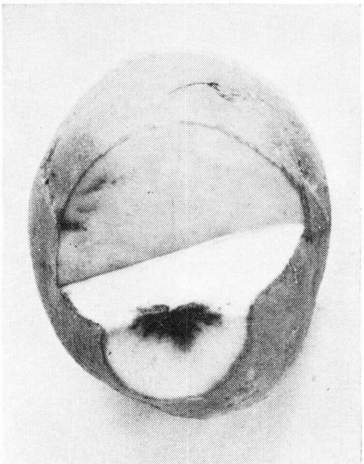

Figure 29.—Green Mountain potato tuber with the stem end sliced off to show that typical stem-end browning does not extend deep.

Although stem-end browning does not affect the edible quality of tubers or their value for seed purposes, it does nevertheless impair their market value because of inspection restrictions. Green Mountain and Irish Cobbler varieties are particularly susceptible to stem-end browning,

but the trouble has not been found in some of the newer varieties, such as Chippewa and Katahdin.

Recommendations for Control

The chief control measures so far indicated for stem-end browning are the planting of nonsusceptible varieties and the use of proper storage temperatures.

HEAT AND DROUGHT NECROSIS

Heat and drought necrosis has been noted in tubers grown in light soils in the hot, arid potato sections of the United States. It has been noted especially in the early crop grown in the volcanic ash soils of Idaho and seems to occur in tubers that are allowed to lie in the hot soils after the vines begin to die. It is marked by a golden-yellow to brown discoloration of the water vessels of affected tubers; the discoloration is most pronounced in the ring tissues at either the stem end or the bud end and in the tissues between the ring and the tuber surface. At first discoloration is restricted to the vascular tissue, but after a time it spreads slightly to surrounding tissues and the color changes from golden yellow to a light or dark brown. The affected tissues die. Upon cutting it is found that the discolorations are not due to a solid dark mass of tissue but to discolored strands which impart a dark hue to the tissue just above them.

Recommendations for Control

Control of heat and drought necrosis involves keeping the soil moist, cool, and shaded and in digging the tubers as soon as the vines begin to die if the soil is light and the weather hot.

FROST OR FREEZING NECROSIS

If exposure to freezing temperatures leads to ice formation in the tissues of potatoes, it may cause a variety of symptoms known as freezing injury. Sometimes these symptoms are general and readily apparent externally; at other times they are localized internally and are visible only upon cutting. The internal type is known as frost or freezing necrosis, whereas the external type is known as freezing. Both types can be detected only after thawing.

Tissues killed by freezing are very wet and usually become infected with bacteria which cause a foul-smelling, slimy or sticky rot if the tissues thaw in a warm, humid atmosphere; or the tissues may dry down to a mealy or tough, leathery, granular, chalky mass if they thaw in cold or dry air. If only one side of a tuber is frozen, the killed part frequently is sharply set off from the unaffected area by a purplish or brown line of corky tissue. Often fusarium rot of the tuber sets in before the unaffected cells are cut off by the corky layer.

Generally, however, freezing necrosis is marked by internal discoloration, of which there are several types. One, the ring type, is limited to the vascular ring and immediately adjoining tissues. Another, the net type, is marked by more or less blackening of the vascular tissue and the fine strands that extend from the vascular tissue into the interior pith and outer tissues (fig. 30). Finally,

there is a blotchy type, marked by irregular patches ranging in color from an opaque gray or blue to sooty black, which may occur anywhere in the tuber. When these blotches are in the outer tissues they may be apparent externally in clear tubers with white skins. This is the only type of freezing necrosis that may be visible externally. Tubers affected with any or all of these types of freezing necrosis generally shrivel or wilt more than nonaffected tubers. However, excessive shriveling alone cannot be relied upon as a sign of freezing necrosis.

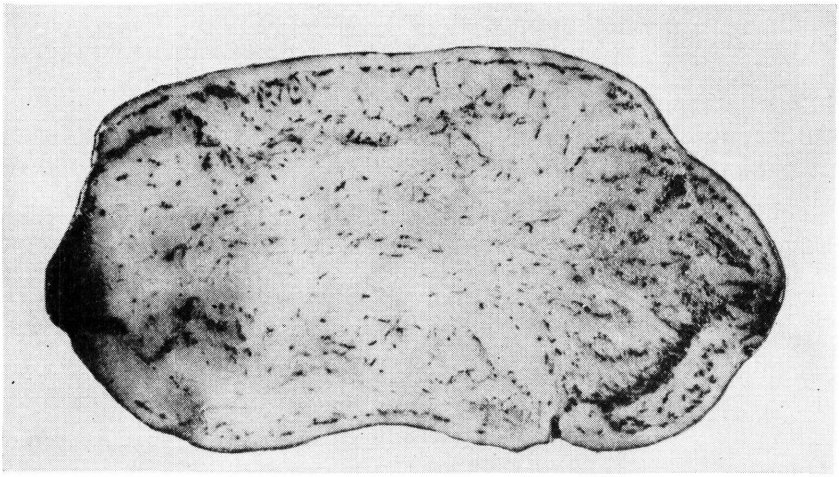

FIGURE 30.—**Potato tuber showing net type of freezing necrosis.**

If tubers are exposed to low temperatures that are not low enough to cause ice formation, the sugars increase and the tubers become sweet. This sweetness disappears, however, if these tubers are kept at temperatures above 40° F. Frozen tissues, however, are no sweeter than unfrozen ones; therefore, sweetness of the tubers is not a sign of freezing injury. Potato tubers will not freeze at 32°. The critical temperature, that is, the temperature at which ice begins to form, lies between 29.5° and 26.6°. It is impossible to forecast the critical temperature for a particular tuber because there are differences in individual susceptibility to freezing. The length of exposure to freezing temperatures is also an important factor. It is not advisable to plant tubers showing severe freezing necrosis, because they usually rot in the soil before sprouting. Potatoes showing only slight freezing necrosis may ultimately produce normal plants, but in general they should not be planted if sound seed stock can be obtained. To prevent freezing injury, tubers should not be exposed to temperatures below 32°.

SUNBURN AND SUNSCALD

Sunburn and sunscald are caused by the exposure of tubers to the sun during growth or after digging, either in the field or in transit or storage.

Sunburn, or greening, results from exposure to light and does not involve the killing of the affected tissues. It frequently occurs in

growing tubers. It is accompanied by a pungent taste and makes tubers unpalatable for most people and even poisonous for a few. With long exposure the outer tissues turn deep green and those underlying greenish yellow or deep yellow. If dug before maturity, tubers turn green or yellow and shrivel more readily than mature ones with well-developed cork layers.

Frequently exposure to sunlight and resulting high temperatures lead to the killing of the cells. This is known as sunscald. Often the affected tubers become watery and turn brown to a considerable depth or throughout. In other cases freshly scalded areas have a blisterlike appearance externally and a metallic color and the underlying tissues are rather watery. Such areas may dry out and appear chalky and granular or hard and leathery. Most frequently, they are attacked by bacteria that cause foul-smelling rots or by the fungus that causes leak.

Recommendations for Control

The only possible control of sunburn and sunscald is to prevent the exposure of tubers to the sun for prolonged periods of time.

SPINDLING SPROUT (HAIR SPROUT)

Spindling sprout, or hair sprout, is characterized by abnormally slender and feeble sprouts (fig. 31). It indicates a constitutional

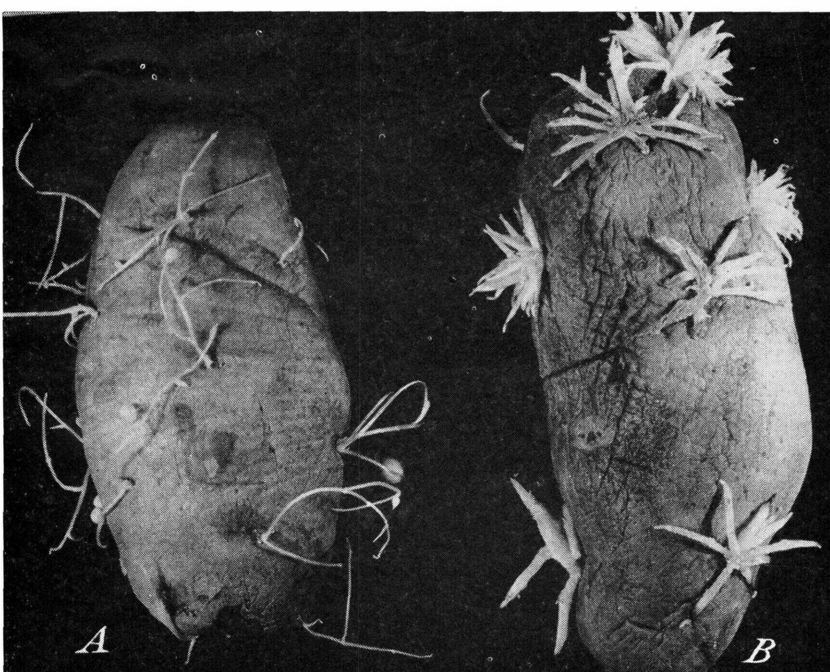

FIGURE 31.—*A*, White Rose potato tuber kept in storage for 12 months, showing spindling sprout; *B*, healthy control tuber.

weakness of the tuber, which may or may not be associated with the presence of other specific diseases.

When the disease is of a nontransmissible type, some of the sprouts have a diameter about half to a fourth that of normal ones; when the seed pieces bearing them are planted, the resulting plants develop small tubers weighing an ounce or less. Experiments carried out in Maine showed that when these small tubers are planted they form stocky, vigorous shoots and develop normal tubers weighing 5 to 7 ounces. When healthy tubers were grafted with plugs from spindling sprout tubers they did not develop spindling sprout.

Spindling sprouts of similar appearance may be symptoms of witches'-broom or leaf roll; such sprouts should not be confused with the nontransmissible type.

Recommendations for Control

Presprouting has been recommended as a method to determine whether spindling sprout is present in seed lots coming from districts where this trouble has been prevalent in the past.

BLACKHEART

Blackheart is a result of asphyxiation of the tissues of the potato tuber. It occurs when the temperature is too high or ventilation is so poor that the supply of oxygen is inadequate and under various combinations of temperature and ventilation.

The symptoms of blackheart vary, depending upon whether the uninjured tubers were exposed to high temperature and a normal air supply or to high, low, or normal temperatures with an insufficient

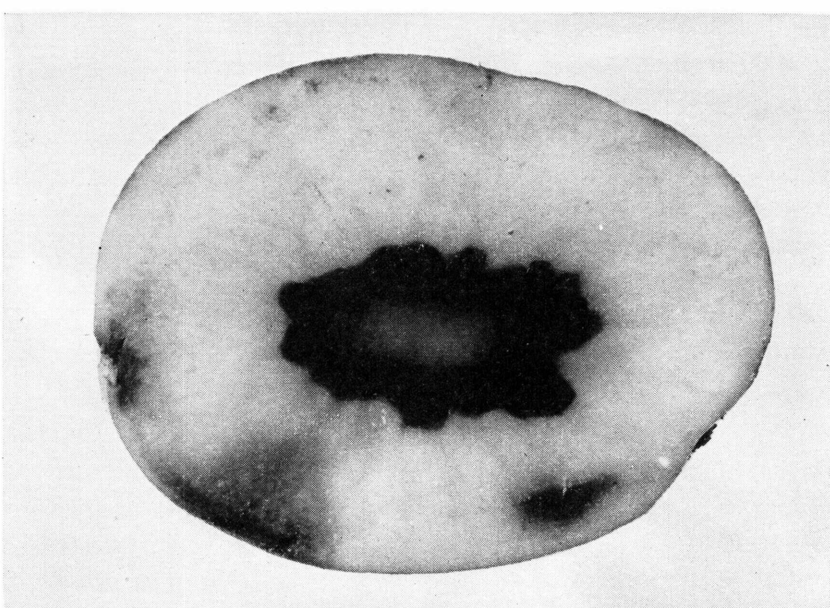

FIGURE 32.—Potato tuber showing blackheart.

air supply. Asphyxiated tissues are easily invaded by bacteria and fungi. These cause various forms of watery or slimy decay, which soon hide the typical blackheart symptoms.

The external symptoms of blackheart are moist areas on the surface which may be purplish at first but turn brown or black within a short time. The internal symptom is a dark-grayish to purplish or inky-black discoloration (fig. 32). Tissues cut soon after the injury are of normal color; shortly after access to the air, however, they turn pink, then gray or purplish, and finally jet black. Sometimes all these colors except pink are found simultaneously in the same tuber. At other times only gray or brown is found, as when tubers are heated above 130° F. or when they are deprived of all oxygen for considerable periods after death as in waterlogged soils or in flooded storage pits.

The discolored areas usually are sharply set off from the healthy tissues. Generally the discoloration is restricted to the heart of the tuber, but frequently it radiates to the exterior also. The discolored regions may appear in zones in the outer parts of the tuber and may be absent or less evident in the center. The affected tissues are firm and even leathery if they have dried a little, quite unlike those affected with leak, which frequently show colors similar to those of blackheart. In advanced stages the affected tissues dry out and cavities result.

Recommendations for Control

As tubers will not develop blackheart at temperatures below 95° F. if given a good supply of air, control involves avoidance of high storage temperatures and provision for good ventilation. The temperatures in heated cars should not be allowed to go above 60° or 70°. To prevent a shortage of oxygen, tubers should not be stored in solid piles more than 6 feet deep even at low temperatures. They should not be left long in hot, light soils after the vines are dead or lying on the surface of the soil after digging during hot weather.

HOLLOW HEART

Hollow heart consists of a more or less irregular cavity in the center of the tuber, usually without any discoloration of the surrounding tissues; occasionally the adjacent cells assume a brownish corky appearance (fig. 33). This abnormal condition is confined commonly to the large tubers and occurs mainly in seasons or under conditions favorable for rapid growth. Hollow heart is not a decay and has no effect on the succeeding crop, but affected stock is undesirable for eating.

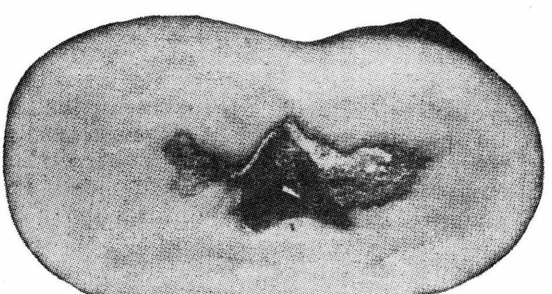

FIGURE 33.—Potato tuber showing hollow heart.

Recommendations for Control

On soils where hollow heart is apt to appear, it can be very largely, if not entirely, avoided by closer spacing of the plants. Closer spacing will make the growth rate less rapid and more even and reduce the tendency of the tubers to split internally.

ENLARGED LENTICELS

Enlarged lenticels occur when potato tubers are left on very wet soil for some time after digging or are stored in a very moist atmosphere. A large number of scablike openings appear in the skin as if pushed out from below; frequently they assume a corky appearance later (fig. 34). This condition is merely the result of an excessive development of the natural pores, or lenticels, which ordinarily appear as inconspicuous slits on the surface of the tuber. No damage is done except from the standpoint of appearance.

FIGURE 34.—Potato tuber with abnormally enlarged lenticels.

SECOND GROWTH (KNOBBY TUBERS)

Second growth, or knobby tubers, may be caused by such diseases as giant hill and yellow dwarf. Some varieties, especially those having long tubers, are more inclined to knobbiness than others. This condition often develops as a result of dry weather that prevails during midseason and is followed by a rainy spell. Under such conditions tuber growth temporarily ceases during the dry weather and is resumed after the rain begins. This causes an abnormal growth response, and knobs result on various parts of the tuber. This trouble may also occur as a result of irregular irrigation.

Recommendations for Control

Proper farm practices and the turning under of sufficient humus to retain the moisture are recommended to avoid second growth.

SECONDARY-TUBER FORMATION (SPROUT TUBERS)

Occasionally seed pieces that develop small new tubers without the formation of sprouts are found; or if sprouts are formed, they terminate in new tubers (fig. 35). This condition is known as secondary-

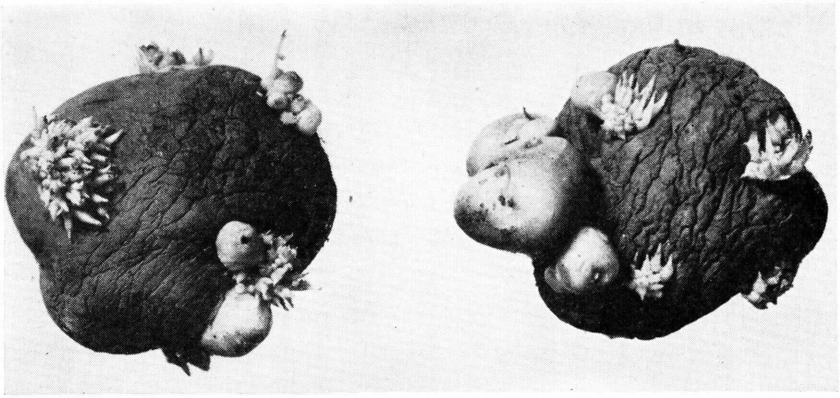

FIGURE 35.—Potato tubers showing secondary or sprout tubers.

tuber formation, sprout tubers, or "potatoes with no tops." Such formation takes place only when the rest period has been completed in the spring after the seed is planted or during the prevalence of conditions unfavorable to normal vegetative growth. The first indication of this trouble in the field is a poor stand. When the seed pieces are examined they are found to be firm, but a small potato about the size of a marble has grown directly from an eye or a short sprout. It is believed that this abnormality is caused by an excessive concentration of the cell sap of the tubers.

Recommendations for Control

Storage that favors early sprouting or unusually long storage in light at a fairly warm temperature, 65° to 68° F., predisposes the potato to form secondary tubers. The most important factors in avoiding sprout tubers are cool storage and late planting.

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